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Predicting First-Run Gunnery Performance on Tank Table VIII

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Human Resources Research Organization

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Research was conducted to determine if performance on the first run of Tank Table VIII can be predicted from amount and level of training on the Unit Conduct-of-Fire Trainer (U-COFT) and from crew turbulence data. During the first phase of the research, intercorrelations were computed between predictor variables and Table VIII performance measures obtained from 77 tank crews. Two predictor variables from U-COFT training correlated significantly with Table VIII performance--crew reticle aim level and TC reticle aim level. Neither variable was able to predict which crews would qualify on Table VIII, but the composite of crew reticle aim and time in crew was able to predict which crews would qualify. This finding was not supported by the results based on 136 crews examined during Phase II. Since gunnery training was curtailed during Phase I but not during Phase II, the Phase I results may be applicable to future training situations in which resource constraints cause training to be curtailed.

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Research Report 1571

Predicting First-Run Gunnery Performance on Tank Table VIII

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Education and Training

FOREWORD

Tank crew gunnery proficiency is assessed on Tank Table VIII, a series of live-fire engagements that are expensive to administer. Crews that fail to qualify on their first run on Table VIII must repeat part or all of these exercises until they qualify and can proceed to section and platoon level gunnery training.

This report describes research designed to decrease the cost of administering Tank Table VIII by predicting which crews will pass and which crews will fail to qualify on their first run. If accurate predictions can be made, crews predicted to fail can receive additional gunnery training on the Unit Conduct-of-Fire Trainer before participating on Table VIII. This procedure would reduce the costs of administering the exercises because it would reduce the need for repeating exercises.

This research is part of the ARI task entitled "Application of Technologies to Meet Armor Skills Training Needs." This task is performed under ARI's Armor Research and Development Activity at Fort Knox. The mission of the task is to design and conduct human performance research in armor gunnery. The report was delivered to the Director of the Directorate of Total Armor Force Readiness at Fort Knox and to the III Corps G3, Training, at Fort Hood.

Training and Doctrine Command is the proponent for this research, and USAARMC is the user (Memorandum of Agreement with ARI entitled "The Effects of Simulators and Other Resources on Training Readiness," 16 January 1989).

EDGAR M. JOHNSON
Technical Director

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PREDICTING FIRST-RUN GUNNERY PERFORMANCE ON TANK TABLE VIII

EXECUTIVE SUMMARY

Research Requirement:

The purpose of this study was to determine if first-run performance on Tank Table VIII can be predicted from amount and level of training on the Unit Conduct-of-Fire Trainer (U-COFT) and from crew turbulence data. If Tank Table VIII performance can be predicted, ammunition can be conserved by delaying a crew's participation on Table VIII until it is likely to qualify on its first run.

Procedure:

The research was conducted in two phases. Table VIII scores, U-COFT training data, and crew turbulence data were obtained from two M1 tank battalions (Phase I) and from four M1 tank battalions (Phase II) assigned to a CONUS post. Intercorrelations were computed between predictor variables and Table VIII performance measures. Regression analyses were performed to determine how well each predictor variable alone could predict performance on Table VIII and how well multiple predictor composites could improve upon these predictions. Scatterplots were drawn to determine the accuracy of the predicted Table VIII scores derived from the individual predictors and from the multiple predictor composites.

Results:

Two predictor variables correlated significantly with Table VIII performance measures during Phase I--level attained within the crew matrix on U-COFT and level attained within the TC matrix on U-COFT. Neither variable, however, was able to predict which crews would qualify on Table VIII. The multiple predictor composites were more successful in predicting Table VIII performance. The composite of crew reticle aim level and time in crew predicted that 12 crews would qualify on their first run on Table VIII and that 65 crews would fail. Half of the crews that were predicted to qualify actually passed the exercise, and 72% of the crews that were predicted to fail actually failed to qualify. Although the results obtained during Phase I appeared to demonstrate that Table VIII performance can be predicted from U-COFT and crew turbulence data, this finding was not supported during Phase II. Since training on Tank Table IV was curtailed during Phase I, but not during Phase II, it is likely that U-COFT contributed more to gunnery skill acquisition during Phase I than during Phase II. Thus, it may be possible to predict first-run performance on Table VIII from U-COFT training and crew turbulence data when resources for gunnery training are curtailed, but not otherwise.

Utilization of Findings:

The findings can be used by armor units to conserve ammunition during the conduct of Table VIII, particularly if ammunition allocations are reduced. U-COFT training and crew turbulence data would be used to identify the crews that are most likely to qualify on their first run on Table VIII, and only those crews would be allowed to participate on the gunnery table. Crews that are identified as likely to fail on their first run would be given additional training on U-COFT, and they would not participate on Table VIII until the predictors indicate that they would be likely to qualify on their first run.

PREDICTING FIRST-RUN GUNNERY PERFORMANCE ON TANK TABLE VIII

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PREDICTING FIRST-RUN GUNNERY PERFORMANCE ON TANK TABLE VIII

INTRODUCTION

Tank Combat Tables

The goal of M1 tank combat training is to achieve and sustain proficiency in gunnery and tactics. Tank crewmen attain proficiency in gunnery primarily by participating in a series of gunnery engagements. The engagements are conducted in a graduated set of twelve gunnery tables that are described in detail in FM 17-12-1, Tank Combat Tables M1 (Department of the Army, 1988). According to the field manual, basic individual and crew skills are trained on Tables I through III and tested on Table IV; intermediate level crew skills are trained on Tables V through VII and tested on Table VIII; and advanced section and platoon skills are trained on Tables IX and XI and tested on Tables X and XII.

Table VIII is one of the most important events in tank gunnery training. Its importance stems from its role as a qualification exercise. A crew cannot participate in the tank tables for section and platoon gunnery training (Tables IX through XII) unless (a) it scores at least 700 points on Table VIII (an average of 70 points for each engagement) and (b) it scores 70 points or more on at least seven of the ten engagements. Crews that fail to qualify on their first run on Table VIII are retested. During the retest, crews will generally fire only the engagements that they previously failed. The commander, however, may require the crew to refire the entire set of engagements or a subset of engagements (e.g., day exercises, night exercises).

Conservation of Ammunition

Conservation of ammunition is an important element in the conduct of Table VIII. Crews are allocated a fixed number of rounds. According to DA Pamphlet 350-38, Standards in Weapons Training (Department of the Army, 1987), the current allocation of rounds for Table VIII is 22 main gun rounds, 250 rounds for the coaxial machinegun, and 50 rounds for the commander's machinegun. If a crew expends its allocation of ammunition before completing all ten engagements or before retesting, there is no requirement to provide the crew additional ammunition. In practice, a company will reallocate ammunition using unexpended rounds obtained from crews that qualified on Table VIII without expending all of their allocated ammunition.

The problem of ammunition conservation is becoming more serious because of reductions in training budgets. If the number of rounds of ammunition allocated for Table VIII is reduced, fewer crews will be able to complete all ten engagements or be retested on the failed engagements. This eventuality would have serious consequences on gunnery training since units cannot continue their gunnery training via the tank tables until all crews have qualified on Table VIII.

If ammunition allocations are reduced, companies may be unable to reallocate ammunition for Table VIII without impeding other live-fire training events. One solution to this problem is to delay a crew's participation on Table VIII until it is likely to qualify on its first run. This would conserve the ammunition that would normally be expended during retested engagements.

The value of the proposed solution to the ammunition conservation problem depends on four requirements: (1) that it is possible to predict first-run performance on Table VIII, (2) that the predictions can be made without additional expenditures of live ammunition, (3) that additional training will improve the likelihood that a crew will qualify on Table VIII during its first run, and (4) that this additional training can be supplied without additional expenditures of live ammunition.

Using the Unit Conduct-of-Fire Trainer and Crew Turbulence to Predict Table VIII Performance

One way to predict performance on Table VIII and to provide additional crew training without expending ammunition is through the use of a gunnery trainer or simulator. Since the Unit Conduct-of-Fire Trainer (U-COFT) is used to achieve and sustain proficiency in tank gunnery skills, it potentially could satisfy all four requirements. The two requirements dealing with ammunition expenditures can obviously be met since U-COFT does not require ammunition. However, there is no firm evidence that performance on U-COFT is predictive of first-run performance on Table VIII or that additional training on U-COFT will increase the likelihood that crews will qualify on their first run. Although several research efforts have been conducted to examine the relationship between training on U-COFT and live-fire gunnery proficiency (Hughes, Butler, Sterling, & Berglund, 1987; Kuma & McConville, 1982; Martellaro, Thorne, Bryant, & Pierce, 1985; Rapkoch & Robinson, 1986), none of the studies is able to supply the required evidence. Crews in three of the research efforts (Kuma & McConville; Martellaro et al.; and Rapkoch & Robinson) did not follow the program of instruction (POI) currently used for sustainment training on the U-COFT. Crews in the fourth research investigation (Hughes et al.) followed the standard POI during training, but none of the crews completed the POI within the allotted U-COFT training period.

Another factor that may affect performance on Table VIII is crew turbulence. A tank crew consists of four crew members--the tank commander (TC), gunner, driver, and loader. Since the successful operation of the tank requires close coordination among these four crewmen, teamwork may suffer whenever there are personnel changes within the crew. Consequently, crew turbulence would be expected to be predictive of first-run performance on Table VIII. That is, it would be expected that the most stable crews would be the most likely to qualify on Table VIII.

Purpose of the Present Research

Given the likelihood that ammunition allocations for tank gunnery training will be reduced, the need to conserve ammunition during training is likely to increase. One way to conserve ammunition without having a severe

impact on training is to delay a crew's participation on Table VIII until it is more apt to qualify on its first run. The primary purpose of the present research was to determine how well first-run performance on Table VIII can be predicted from the amount and level of training on U-COFT and from crew turbulence.

This research was conducted in two phases. The objective of Phase I was to develop a model, based on significant relationships between first-run Table VIII performance and U-COFT and crew turbulence variables, which could be used to predict Table VIII scores. The objective of Phase II was to cross-validate the model derived during the Phase I analysis and to replicate the procedures used in Phase I in an attempt to improve the validity of the model.

PHASE I

Method

Participants

Table VIII, U-COFT, and crew turbulence data were obtained in 1989 from two M1 tank battalions (77 crews) stationed at a Continental U.S. (CONUS) post.

Predictor Variables

Two sets of variables were examined in the study to determine their ability to predict Table VIII performance: (a) variables related to training on U-COFT and (b) crew turbulence. U-COFT variables included measures of U-COFT proficiency and amount of U-COFT training. Crew turbulence focused on the amount of time that the TC and gunner were together in those positions in the same crew.

M1 U-COFT

Crew training on the M1 U-COFT. The M1 U-COFT is among the most widely used simulators for tank gunnery training. The U-COFT was designed to train and sustain critical gunnery skills under simulated conditions. According to FC 17-12-7-1, M1 Unit Conduct-of-Fire Trainer (U-COFT) Training Device Support Package (U.S. Army Armor Center, 1985), U-COFT can be used to simulate all or portions of the basic and intermediate tank gunnery tables (Tank Gunnery Tables I-VIII). U-COFT exercises, however, were not meant to replace the tank gunnery tables. Instead, they were intended as an additional means of training and maintaining the individual and crew skills that are trained by the basic and intermediate gunnery tables.

The M1 U-COFT is a whole-task gunnery simulator that was developed to train TC and gunner teams. The U-COFT contains simulated TC and gunner crew stations and presents computer-generated images of targets in the TC and

gunner sights. Crews[1] are instructed to go through the actual engagement procedures necessary to produce simulated target "kills."

Four types of gunnery training are supported by U-COFT programs: (a) basic gunnery training of non-armor personnel so that they can serve as battlefield replacements; (b) transition training of tank crewmen who are converting from the M60 to the M1 tank; (c) cross training of M1 drivers and loaders for the gunner's position or of gunners for the TC's position; and (d) sustainment training for TCs and gunners with M1 experience.

U-COFT exercises. There are 685 training exercises available on the U-COFT. Each exercise contains from four to ten engagements. The engagements cover a broad range of target engagement conditions by simulating a variety of tactical scenarios, weather and visibility conditions, and levels of equipment readiness. The exercises are controlled by an instructor/operator (I/O). The I/O's responsibilities include initiating the exercises, acting as the driver and loader, monitoring crew performance, and providing crews with performance feedback.

The U-COFT exercises are described in detail in the Instructor's Utilization Handbook for the M1 Unit-Conduct of Fire Trainer (U-COFT) (General Electric, 1985). The exercises are organized into two training matrices--a TC matrix and a crew matrix. All targets in the TC matrix must be engaged by the TC from the Commander's Weapon Station (CWS). The TC can fire the main gun, the coaxial machinegun, or the commander's machinegun. When firing the main gun or the coaxial machinegun, the TC must use the Gunner's Primary Sight Extension (GPSE) and the commander's override. Although the gunner is present in the simulator, he is instructed not to identify targets acquired by the TC. Since the TC cannot use the Gunner's Auxiliary Sight (GAS), only precision and battlesight engagements can be fired when using the main gun or the coaxial machinegun.

The crew matrix contains exercises that are fired by the TC and gunner as a team. The TC can fire the same weapon systems in the crew matrix as in the TC matrix. In addition, the gunner can engage targets with either the main gun or the coaxial machinegun using either the Gunner's Primary Sight (GPS) or the GAS. Precision and battlesight engagements can be fired using the GPS, and degraded mode engagements can be fired using the GAS.

Each matrix depicts three gunnery skill dimensions or areas: (a) target acquisition (skills necessary to acquire and identify targets); (b) reticle aim (skills necessary to aim and fire at targets); and (c) system management (skills necessary to operate the fire control system). The two matrices are presented in Appendix A. The participants (TC or crew) train on U-COFT by going through exercises that are defined by the different cells in the matrix. The exercises can be selected by the computer or by the I/O. The U-COFT computer regulates advancement by selecting exercises based on performance on previous U-COFT exercises. The computer can cause a TC or crew to repeat an

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[1]The U-COFT is configured to train only the TC and gunner crew positions. Therefore, the term "crew" refers to just the TC and gunner when used in reference to U-COFT throughout this report.

exercise, move to a more difficult exercise, or move to a less difficult exercise. The I/O has the option of manually selecting exercises to emphasize certain skill areas. Performance on these optional exercises is not taken into account by the computer when regulating advancement through the matrix.

U-COFT predictor variables. Crews in the present study followed the standard U-COFT POI for sustainment training of M1 gunnery skills. Two variables were obtained from U-COFT training printouts and examined to determine how well they could predict first-run Table VIII performance. These predictor variables were (a) proficiency on U-COFT and (b) amount of training on U-COFT. Data on proficiency and amount of training were obtained from both the TC and the crew matrices. Thus, the two indicators of proficiency were (a) the reticle aim level achieved by the TC in the TC matrix and (b) the reticle aim level achieved by the crew in the crew matrix. The four indicators of amount of U-COFT training were (a) the number of computer recommended exercises completed by the TC in the TC matrix, (b) the total number of exercises (computer recommended exercises plus I/O selected exercises) completed by the TC in the TC matrix, (c) the number of computer recommended exercises completed by the crew in the crew matrix, and (d) the total number of exercises completed by the crew in the crew matrix.

Crew Turbulence

Although there are four crewmen in a tank crew, only the TC and the gunner can participate on U-COFT. Consequently, the number of months that the TC and gunner had served together in the same crew, as TC and gunner, was selected as the measure of crew turbulence.

Performance Variables

Tank Table VIII

Engagements. Table VIII consists of ten engagements (referred to as tasks in FM 17-12-1) selected from among fourteen different engagements described in FM 17-12-1. The fourteen engagements represent various combinations of five factors: (1) whether the firing tank is moving or stationary, (2) whether the primary or auxiliary sight is used to engage the targets, (3) whether the precision or battlesight engagement technique is used, (4) whether the engagement is conducted during the day or at night, and (5) the nature of the target. The fifth factor is a heterogeneous category that includes single targets (stationary and moving), multiple main gun targets (stationary and moving), and simultaneous targets (stationary). Table VIII consists of two parts--Table VIIIA and Table VIIIB. Table VIIIA comprises engagements that are fired during the day, and Table VIIIB comprises engagements that are fired at night. Each engagement (day or night) consists of one or two targets. These targets can be stationary or moving and are engaged from either a stationary or moving tank. The crews in the present study fired the same 10 engagements, which are described in Table 1. Tasks 1 through 6 were fired during the day and constituted Table VIIIA; tasks 7 through 10 were fired at night and constituted Table VIIIB.

Table 1

Tank Table VIII Engagements Fired

	Task	Time	Own Tank (Situation)	Conditions	Target 1 (Range)	Target 2 (Range)
1	A1	Day	Stationary (Defensive)	GAS, Battlesight, Computer & LRF failure	Moving T-72 (900-1300m)	Stationary T-72 (900-1300m)
2	A2	Day	Stationary (Defensive)	Simultaneous, GPS, Precision	Stationary BMP (900-1100m)	Troops (400-600m)
3	A3	Day	Moving (Offensive)	GPS	Troops (400-600m)	Troops (700-900m)
4	A4	Day	Moving (Offensive)	NBC, GPS, Precision	Stationary T-72 (1400-1600m)	Stationary T-72 (1400-1600m)
5	A5A	Day	Moving (Offensive)	GPS, Precision	Stationary T-72 (1400-1600m)	Moving T-72 (1400-1600m)
6	B1S	Day	Stationary (Defensive)	3-Man Crew, GPSE, Precision	Stationary T-72 (1400-1600m)	None
7	B2	Night	Stationary (Defensive)	GPS, Precision	Stationary BMP (1200-1400m)	Stationary BMP (1200-1400m)
8	B3	Night	Moving (Offensive)	NBC, GPS, Precision	Stationary BMP (400-600m)	Troops (400-600m)
9	B4	Night	Moving (Offensive)	GPS, Precision	Stationary T-72 (1300-1500m)	Moving T-72 (1300-1500m)
10	B5A	Night	Stationary (Defensive)	GPS, Precision	Moving T-72 (1700-1900m)	None

Note. The order in which crews fired the engagements varied. GAS = Gunner's Auxiliary Sight. LRF = Laser Range Finder. GPS = Gunner's Primary Sight. GPSE = Gunner's Primary Sight Extension used by the TC. NBC = Protective masks worn by crewmen. T-72 = Soviet tank. BMP = Soviet personnel carrier.

Some targets on Table VIII are to be engaged only by the gunner (i.e., targets requiring the use of the GAS and the GPS, and those engaged under NBC conditions), and three are to be engaged by the TC alone (i.e., one target requiring the use of the GPSE and two targets engaged with the commander's machinegun). All other targets can be engaged by either the TC or the gunner. Consequently, the further the TC has progressed within the TC matrix, and the further the TC and gunner have progressed within the crew matrix, the better their performance should be on Table VIII.

Scoring. The raw score which crews receive on each of the tasks in Table VIII is based on engagement speed and accuracy and on threat capability. A crew can earn up to 100 raw points for their performance on each of the ten tasks in Table VIII. However, from 5 to 30 crew duties penalty points (commonly referred to as crew cuts) can be subtracted from each raw score for procedural errors. There are three types of procedural errors: failure to use correct engagement techniques or methods (5 point penalty), failure to adhere to safety rules (10 point penalty), and failure to follow the conditions specified by the task (30 point penalty). A score of 0 points is awarded whenever the penalty points for a task exceed the raw score since the total score received by a crew on a task cannot be negative. Thus, a crew can earn from 0 to 100 points on each of the 10 tasks. These points are then summed to determine the crew's Table VIII score. Crews must obtain a minimum score of 700 of the 1,000 points possible to qualify on Table VIII.

Performance measures. Performance data were extracted from the Table VIII scoresheets provided by the participating battalions. The information recorded on the scoresheets for each engagement was used to calculate five measures of overall Table VIII performance: average raw score, average cuts, average total score, average opening time, and percent hits. While it is more common to use total scores, averages were used so that crews missing data for one or more tasks could be included in the analyses. The average measures can be multiplied by 10 to convert them to total measures.

In addition to the five measures of overall performance on Table VIII, three measures of main gun performance were calculated: firing rate, hit proportion, and hit rate. The measures of main gun performance on Table VIII were included in the analyses as an alternative to the usual means of measuring o. gunnery proficiency on Table VIII (i.e., total score). Gunnery measures are typically derived from the variables of time, rounds, targets, and hits. However, no one metric can encompass all of these variables. Hoffman and Witmer (1989) suggested using the composite metric hit rate as the primary measure of crew gunnery proficiency. Hit rate (hits/time) is an indicator of the speed with which crews achieved hits. Firing rate (rounds/time) is an indicator of how fast crews were able to fire rounds, regardless of accuracy. Hit proportion (hits/rounds) is an indicator of crew firing accuracy. Hit rate can therefore be calculated from firing rate and hit proportion (hits/time = hits/rounds x rounds/time). If hit rate is weighted by the number of targets presented, the resulting metric then includes the variables of hits, time, and targets. Although calculating hit rate in this manner ignores the variable rounds, hit rate is influenced by the number of rounds fired in that having to fire extra rounds increases the time required to attain a hit.

Descriptions of each of the overall and main gun measures of Table VIII performance are presented in Table 2. The procedures for calculating each of the overall and main gun measures are shown in Appendix B.

Analyses

Three types of analyses were performed--descriptive statistics, intercorrelations, and regression analyses.

Descriptive Statistics

The descriptive statistics were calculated to summarize the following: (a) measures of first-run performance on Table VIII; (b) measures of major portions of Table VIII performance, that is, separate summary statistics for day tasks (Table VIIIA), night tasks (Table VIIIB), offensive tasks (engagements fired from a moving tank), and defensive tasks (engagements fired from a stationary tank); and (c) the predictor variables (U-COFT proficiency, amount of U-COFT training, and crew turbulence).

Table 2

Table VIII Performance Variables

Variable	Description
	Overall Measures
Average Raw Score	Mean raw score for the tasks fired.
Average Cuts	Mean number of procedural cuts for the tasks fired.
Average Total Score	Mean total score for the tasks fired.
Average Opening Time	Mean opening time for the tasks fired.
Percent Hits	Hits per targets presented.
	Main Gun Measures
Firing Rate	Rounds fired over time.
Hit Proportion	Targets hit per rounds fired.
Hit Rate	Targets hit over time.

Intercorrelations and Correlations

The following intercorrelations were obtained: (a) intercorrelations among the predictor variables, (b) intercorrelations among the performance measures, and (c) correlations between the predictor variables and the performance measures.

Regression Analyses

Regression analyses were used to form multiple regression equations utilizing predictor composites. Predicted average total scores were then calculated from these composite equations and plotted against average total scores to determine the utility of the predictor composites.

Results

Descriptive Statistics

Table VIII Performance Measures

Summary statistics. Table 3 contains summary performance statistics for Table VIII engagements overall and for the main gun engagements. The mean total score for an engagement was 61.29. Multiplying this mean total score by ten (the total number of engagements) provides the mean total score for Table VIII. The mean total score (612.9) is almost 90 points below the minimum score of 700 that is required for crew qualification. The summary statistics suggest that, on the average, crews failed to qualify because their opening time was too long (8.75 seconds), they hit only 61% of the targets

Table 3

Summary Statistics for Table VIII Overall and Main Gun Performance Variables

	All Engagements					Main Gun Engagements		
	Average Raw Score	Average Cuts	Average Total Score	Average Opening Time	Percent Hits	Firing Rate	Hit Proportion	Hit Rate
Minimum	26.10	0.00	23.70	3.33	29.2	4.49	0.32	1.97
Maximum	95.70	8.50	95.20	21.50	100.0	13.00	1.00	9.61
Mean	63.13	2.47	61.29	8.75	60.9	7.97	0.73	5.88
S.D.	15.35	2.00	15.33	3.61	10.7	1.66	0.15	1.85

Note. N = 77.

(73% of the main gun targets), their firing rate for the main gun was too low (8 rounds per minute), or some combination of these factors.

Performance distributions. The distributions of the overall variables are presented in Figures 1 through 5. The distributions for Table VIII raw scores (Figure 1) and total scores (Figure 2) appear to approximate normality. Only 24 of the 77 crews in the sample (31%) earned a total score equal to or greater than the 700 points needed to qualify. Thus, 69% of the crews in the sample had to refire at least some of the Table VIII exercises. The percentage of crews that qualified is substantially below the 95.5% of crews that were reported by Hoffman (1989) to have passed Table VIII at Grafenwoehr. Hoffman, however, acknowledged that the Grafenwoehr scores could have included reruns. If so, any comparison between the two sets of scores would have little meaning.

Crew cuts (crew duties penalty points) appeared to have little effect on Table VIII scores since crews were penalized, on the average, less than three points per engagement. The distribution of crew cuts, shown in Figure 3, is positively skewed. That is, more crews had a small number than a large number of crew cuts.

The mean opening time for Table VIII was 8.75 seconds. The distribution of opening times, shown in Figure 4, is positively skewed. Thus, more than half of the crews had average opening times of 8.00 seconds or less even though the average opening time was 8.75. Crews hit 61% of the targets, on the average, and the distribution of percent hits, which is shown in Figure 5, was approximately normal.

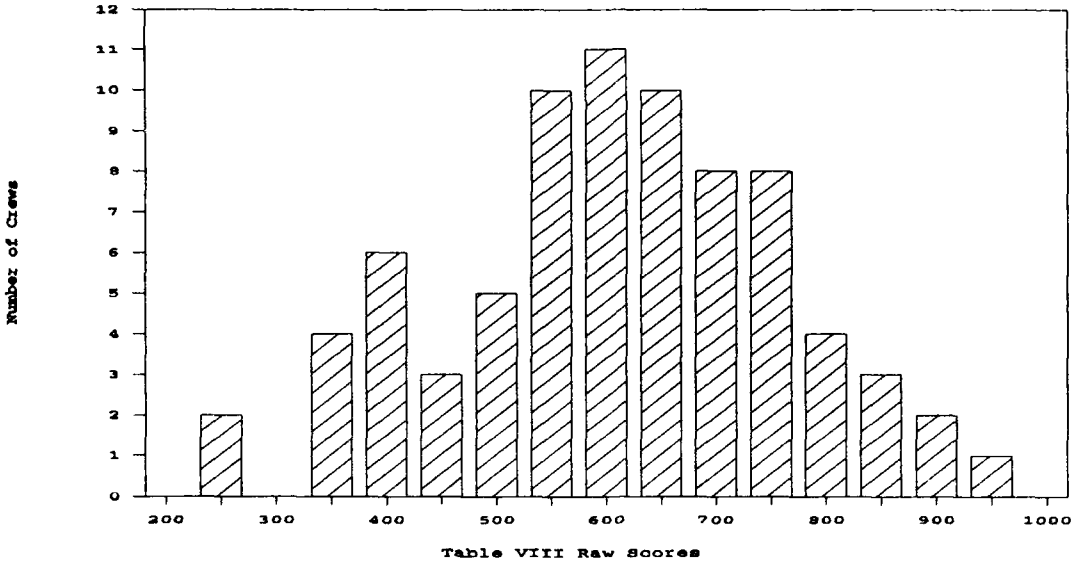

Figure 1. Distribution of Table VIII raw scores (average raw score multiplied by 10).

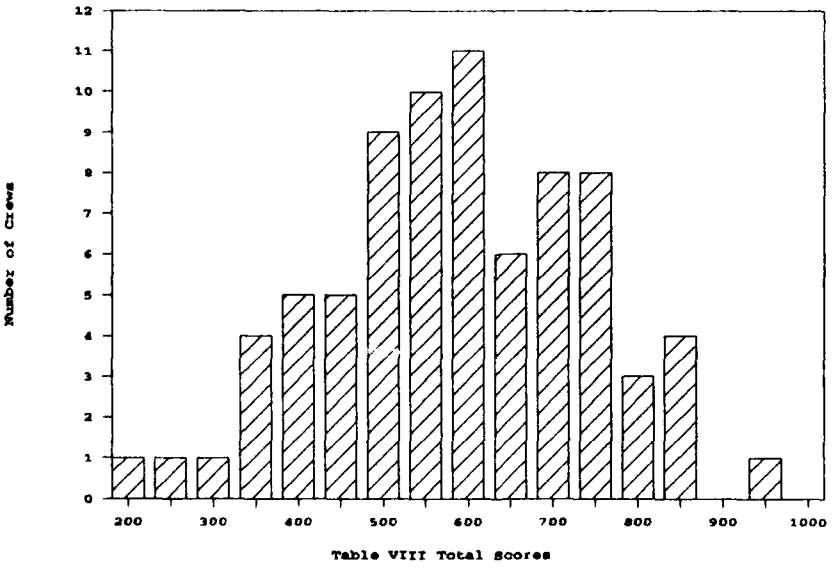

Figure 2. Distribution of Table VIII total scores (average total score multiplied by 10).

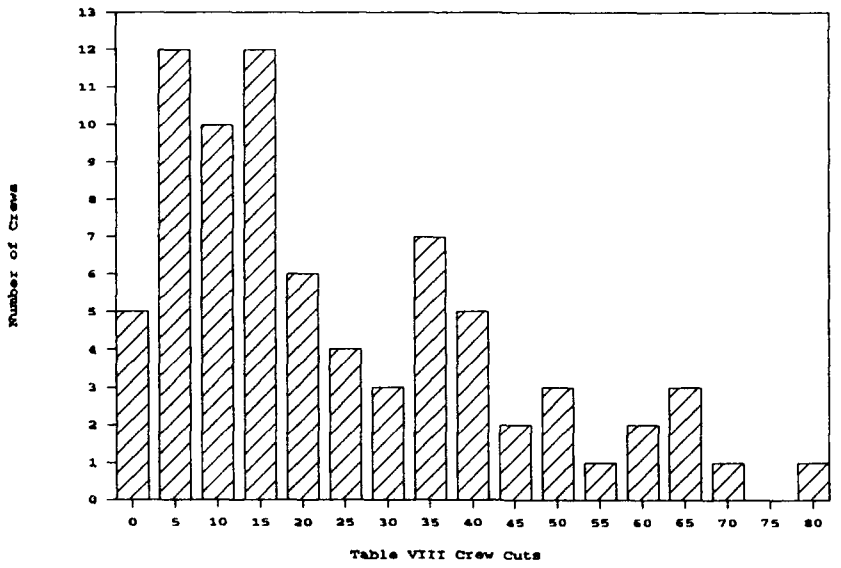

Figure 3. Distribution of Table VIII crew cuts (average cuts multiplied by 10).

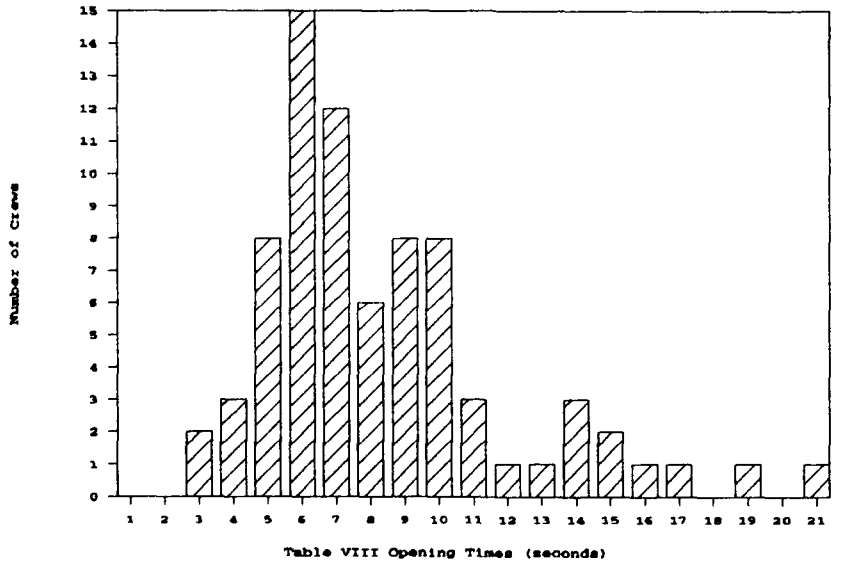

Figure 4. Distribution of Table VIII average opening times.

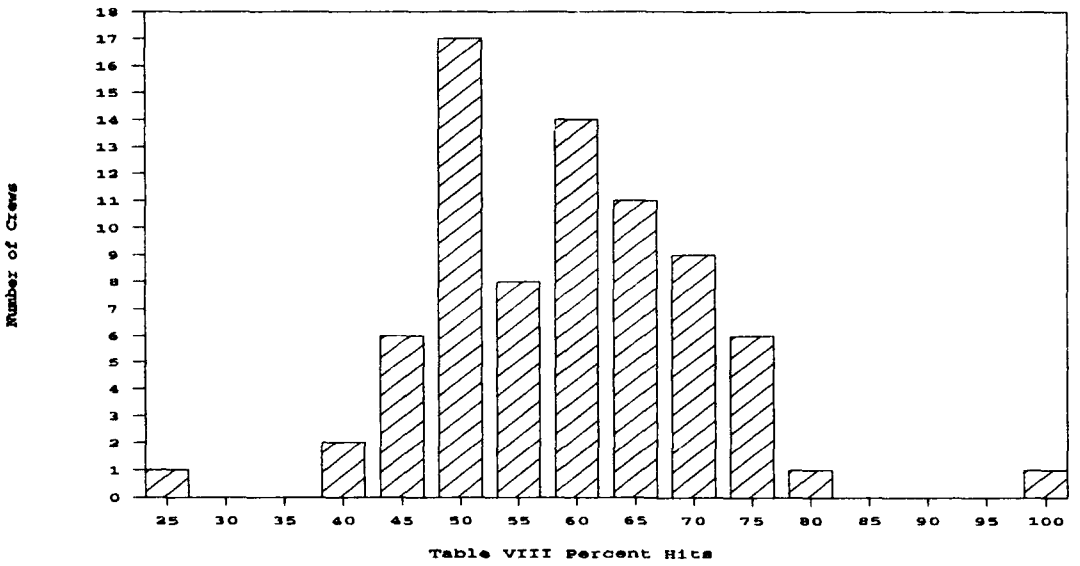

Figure 5. Distribution of Table VIII percent hits.

Performance Measures for Major Portions of Table VIII

Comparisons of performance on day and night tasks and on offensive and defensive tasks are presented in Tables 4 and 5.

Day versus night. Table 4 shows the descriptive statistics for overall performance and main gun performance measures for day and night tasks. Performance was clearly better during the day than at night, as both raw scores [$F(1,71) = 45.708$, $p < .01$] and total scores [$F(1,71) = 46.478$, $p < .01$] were significantly higher for day tasks than night tasks. This result can be explained by the fact that crews had significantly fewer crew cuts [$F(1,76) = 13.490$, $p < .01$], faster opening times [$F(1,70) = 14.430$, $p < .01$], higher main gun hit rates [$F(1,70) = 19.567$, $p < .01$], and higher main gun hit proportions [$F(1,70) = 23.855$, $p < .01$] during the day. The only performance measure on which crews scored significantly lower during the day than at night was overall percent hits [$F(1,70) = 34.050$, $p < .01$].

Offense versus defense. Table 5 shows the descriptive statistics for the overall performance and main gun performance measures for offensive and defensive tasks. There was virtually no difference between the overall performance of offensive and defensive tasks as indicated by the raw scores and the total scores. For many of the remaining performance variables, however, performance was better on offensive tasks than defensive tasks as crews had significantly faster opening times [$F(1,76) = 13.490$, $p < .01$], higher hit percentages [$F(1,76) = 161.823$, $p < .01$], faster main gun firing rates [$F(1,76) = 101.469$, $p < .01$], and higher main gun hit rates [$F(1,76) = 59.350$ $p < .01$] on the offensive tasks. The better performance during

Table 4

Descriptive Statistics of Table VIII Overall and Main Gun Performance Measures for Day and Night Tasks

	All Engagements										Main Gun Engagements					
	Average Raw Score		Average Cuts		Average Total Score		Average Opening Time		Percent Hits		Firing Rate		Hit Proportion		Hit Rate	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Min:	26.83	0.00	0.00	0.00	26.83	0.00	3.17	2.75	0.29	0.14	3.95	3.58	0.31	0.19	2.15	1.02
Max:	100.00	100.00	10.83	15.00	99.17	98.75	16.50	38.50	1.00	1.00	13.49	15.00	1.00	1.00	11.80	14.69
Mean:	71.28	49.93	2.08	2.97	69.57	48.08	7.57	10.58	0.57	0.72	8.22	7.62	0.79	0.65	6.49	5.05
S.D.:	17.53	25.00	2.40	2.87	17.66	24.87	2.90	7.18	0.10	0.21	2.03	2.60	0.16	0.24	2.07	2.77

Note. N = 77 for all performance measures for day tasks. N = 71 for all performance meaures for night tasks except average raw score, average cuts, and average total score, for which N = 72.

Table 5

Descriptive Statistics of Table VIII Overall and Main Gun Performance Measures for Offensive (Off) and Defensive (Def) Tasks

	All Engagements										Main Gun Engagements					
	Average Raw Score		Average Cuts		Average Total Score		Average Opening Time		Percent Hits		Firing Rate		Hit Proportion		Hit Rate	
	Off	Def	Off	Def	Off	Def	Off	Def	Off	Def	Off	Def	Off	Def	Off	Def
Min:	9.40	16.20	0.00	0.00	7.40	15.20	2.80	3.60	0.25	0.19	3.50	2.94	0.14	0.07	1.17	0.21
Max:	100.00	97.60	12.00	14.00	100.00	97.60	23.67	27.20	1.00	1.00	20.50	10.16	1.00	1.00	15.51	9.08
Mean:	64.15	62.43	2.06	2.84	62.74	60.20	7.54	9.87	0.79	0.52	9.64	6.31	0.75	0.71	7.37	4.59
S.D.:	21.06	18.01	2.51	3.01	21.08	17.88	4.58	4.46	0.19	0.11	2.69	1.56	0.21	0.18	3.05	1.74

Note. N = 77.

offensive tasks is somewhat unexpected given the difference in scoring offensive and defensive engagements on Table VIII. Timing during offensive tasks begins as soon as the target is activated. During defensive tasks, timing does not begin until the firing tank moves from turret to hull defilade and is exposed to the target. Thus, the time required to acquire targets, issue fire commands, set the fire control switches, and make the initial target lay should not be reflected in the performance measures during defensive tasks. Despite the performance advantages provided by the timing of defensive tasks, crews apparently performed better during offensive tasks.

Predictor Variables

Summary statistics. Summary statistics for the U-COFT training variables and the crew turbulence variable are shown in Table 6. The crews completed an average of 38.4 computer exercises and attained an average reticle aim level of 26. Level 26 is in reticle aim group 4 of the crew training matrix. The tasks in group 4 require crews to fire at moving targets from stationary tanks. Thus, on the average, crews practiced firing at stationary targets from stationary and moving tanks (crew reticle aim groups 2 and 3) on U-COFT. On the average, crews also received some practice firing at moving targets from stationary tanks (crew reticle aim group 4) on U-COFT, but they did not practice firing at moving targets from moving tanks (crew reticle aim group 5). Similarly, the TCs attained an average reticle aim level of 15 in the TC training matrix. Therefore, on the average, TCs had practiced firing at stationary targets from stationary and moving tanks on U-COFT (TC reticle aim levels 1, 2, and 3), but did not practice firing at moving targets from either stationary or moving tanks (TC reticle aim levels 4 and 5). As a consequence, many of the TCs and crews in this study did not practice on U-COFT firing under all of the engagement conditions that are required on Table VIII.

Table 6

Summary Statistics for Predictor Variables

	TC Computer Exercises	TC Total Exercises	TC Reticle Aim Level	Crew Computer Exercises	Crew Total Exercises	Crew Reticle Aim Level	Time In Crew (Months)
Minimum	0.00	0.00	6.00	0.00	4.00	10.00	0.50
Maximum	24.00	27.00	21.00	72.00	100.00	39.00	30.00
Mean	11.91	14.26	15.21	38.42	65.48	26.29	5.07
S.D.	6.34	7.17	4.31	17.49	22.72	8.19	4.72

Note. N = 77. TC = Tank commander.

Although the crews completed an average of 65 total exercises on U-COFT, only 38 of these exercises (58%), on the average, were computer selected exercises. The remaining 27 exercises (42%) were selected by the I/Os. In contrast, the TCs completed an average of 14 total exercises in the TC matrix, but only 2 (14%) were selected by the I/Os. This discrepancy in the proportion of I/O selected exercises implies that the I/Os emphasized crew-fired over TC-fired exercises.

The TCs and gunners in this study had been together for an average of 5 months (see Table 6). Because this mean was influenced by a single crew that had been together for 2-1/2 years, the median (3 months) is probably a better indicator of crew turbulence than the mean. A median of 3 months indicates that only 50% of the crews were together for more than 3 months. Only 25% of the crews were together for more than 6 months, and only 4% were together more than a year. These data confirm that crew turbulence is a major problem for unit trainers. Because tank gunnery requires a high degree of coordination between crew members, an increased amount of training time would probably be required to overcome the effects of the high turbulence rate.

U-COFT distributions. The distributions of the U-COFT predictor measures are presented in Figures 6 through 9. The distribution of the reticle aim levels that were achieved in the crew matrix is presented in Figure 6. Although reticle aim level 26 was the mean level achieved in the crew matrix, the level that was attained most often was level 39, the highest possible reticle aim level; sixteen of the 77 crews (21%) had completed the entire crew matrix. None of the crews were in reticle aim group 1 (levels 1-7), and only four crews were in reticle aim group 2 (levels 8-14). The distribution of the reticle aim levels that were achieved in the TC matrix is presented in Figure 7. The distribution within the TC matrix is similar to the distribution within the crew matrix. Although level 15 was the average reticle aim level achieved within the TC matrix, the level that was attained most often was level 21, the highest possible reticle aim level; 17 of the 77 TCs (22%) had completed the entire matrix. None of the TCs were in reticle aim group 1, but 12 of the TCs (16%) were in reticle aim group 2.

The distributions of the computer and total exercises completed in the crew matrix are presented in Figure 8. Although crews completed an average of 65 total exercises, the distribution was negatively skewed. That is, the largest number of crews (46) completed between 71 and 90 exercises, and relatively few crews (12) completed fewer than 41 exercises. The distribution of computer exercises was more normally distributed around the mean of 38 with only one crew having completed more than 60 computer exercises.

The distributions of the computer and total exercises completed in the TC matrix are presented in Figure 9. Unlike the negatively skewed distribution of total exercises completed in the crew matrix, the distribution of total exercises completed in the TC matrix was approximately normal.

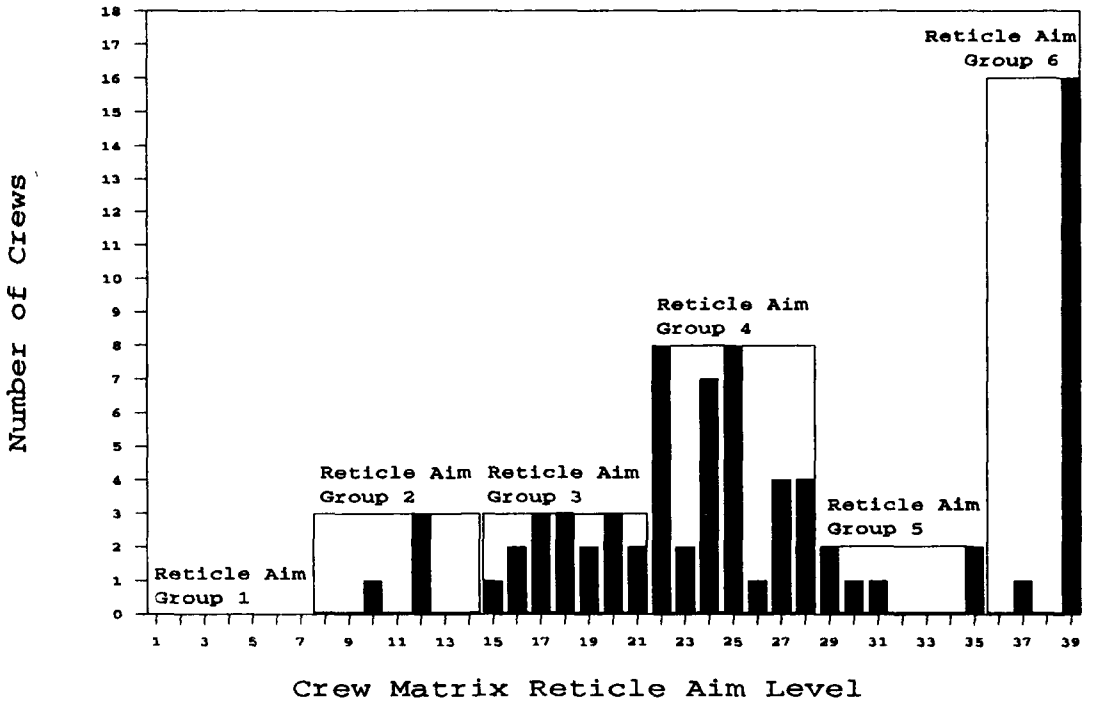

Figure 6. Distributions of crew matrix reticle aim level and reticle aim group.

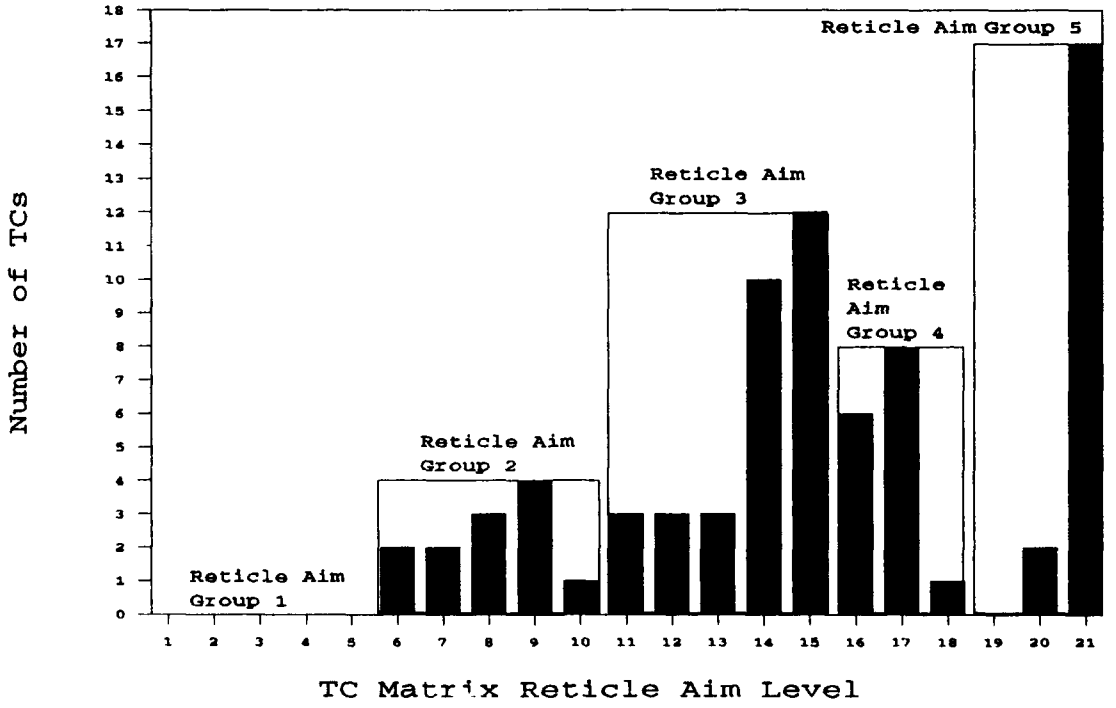

Figure 7. Distributions of TC matrix reticle aim level and reticle aim group.

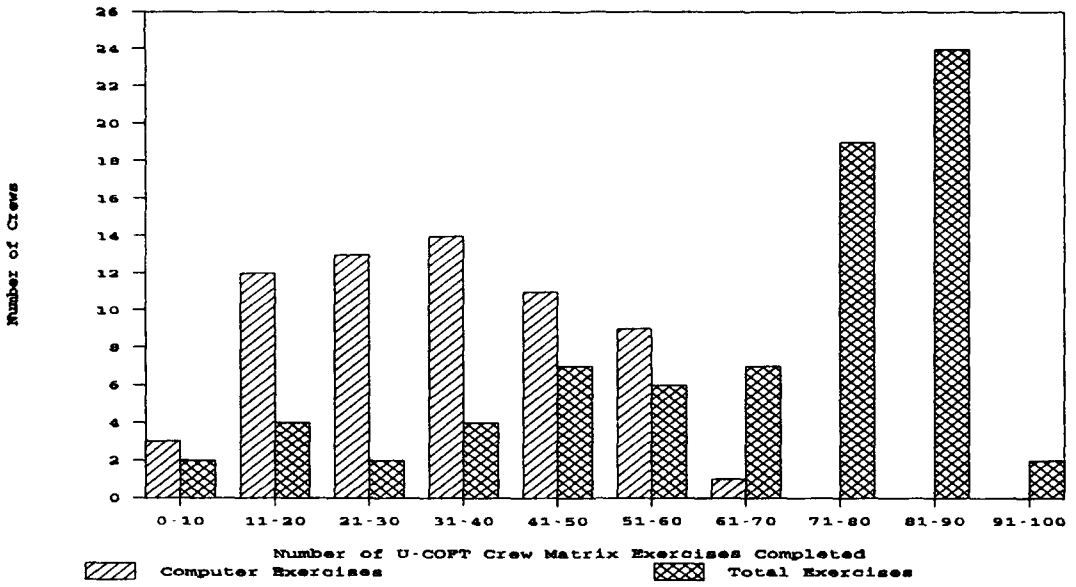

Figure 8. Distributions of the number of computer and total exercises completed in the crew matrix.

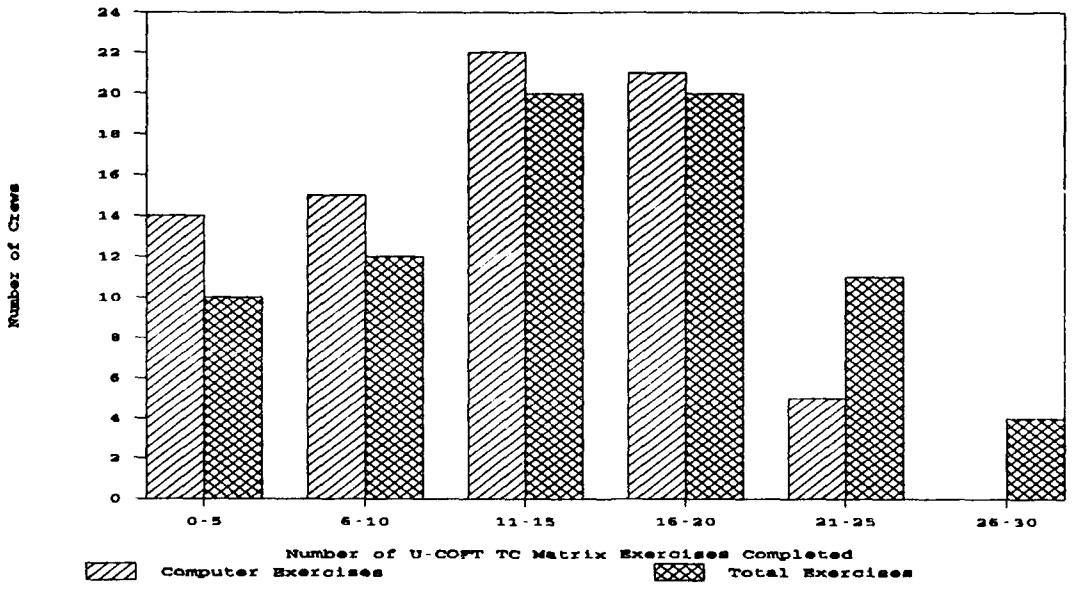

Figure 9. Distributions of the number of computer and total exercises completed in the TC matrix.

Intercorrelations and Correlations

Table VIII Performance Measures

Intercorrelations among the overall performance measures are presented in Table 7. As expected, there is an extremely high relationship between average raw scores and average total scores (r = .99). The influence of average opening time, percent hits, firing rate, and hit proportion on Table VIII performance is suggested by the significant correlations between these variables and average raw and average total score.

Table 7

Correlations Among Table VIII Performance Measures

	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Proportion	Hit Rate
Avg Raw Score	1.00							
Avg Cuts	-.12	1.00						
Avg Total Score	.99**	-.21	1.00					
Avg Open Time	-.53**	.14	-.52**	1.00				
Percent Hits	.71**	-.01	.67**	-.37**	1.00			
Firing Rate	.41**	-.01	.41**	-.53**	.19	1.00		
Hit Proportion	.75**	-.13	.75**	-.30*	.77**	.21	1.00	
Hit Rate	.74**	-.09	.74**	-.52**	.61**	.77**	.77**	1.00

Note. N = 77.
*p < .05. **p < .01.

Performance Measures for Major Portions of Table VIII

Day versus night. Correlations between the performance measures for tasks conducted during the day and those conducted at night are presented in Table 8. Only two of the eight measures obtained during the day exercises correlated significantly with the same measure obtained during the night exercise--hit proportion (r = .23) and hit rate (r = .27). These results tend to support the findings by Hoffman (1989) that Table VIII scores for day engagements show little relation to Table VIII scores for night engagements. One possible reason for the lack of relationship between the two types of tasks is that different crew skills may be required for day gunnery tasks than for night gunnery tasks.

Table 8

Correlations Between Table VIII Performance Measures for Day and Night Tasks

	Day Tasks							
	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
Night Tasks								
Avg Raw Score	.19	.01	.18	.05	.26*	.05	.35**	.28*
Avg Cuts	.11	.09	.09	-.13	.18	.23*	-.01	.17
Avg Total Score	.18	.01	.17	.06	.24*	.03	.34**	.26*
Avg Open Time	-.34**	.01	-.33**	.19	-.25*	-.02	-.35**	-.23*
Percent Hits	.12	.06	.10	.03	.19	.03	.22	.17
Firing Rate	.26*	-.05	.26*	-.06	.22	.00	.37**	.25*
Hit Proportion	.08	.01	.08	-.01	.18	.07	.23*	.23
Hit Rate	.13	-.01	.12	.00	.18	.07	.31*	.27*

Note. N = 71 for all correlations except those that include the performance variables average raw score, average cuts, and average total score, for which N = 72.
*p < .05. **p < .01.

Offense versus defense. Correlations between the performance measures for offensive tasks and the performance measures for defensive tasks are presented in Table 9. Five of the eight measures obtained during offensive exercises correlated significantly with the same measures obtained during defensive exercises. These results imply that the same crew skills are required for offensive and defensive gunnery tasks.

Table 9

Correlations Between Table VIII Performance Measures for Offensive and Defensive Tasks

	Offensive Tasks							
	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
Defensive Tasks								
Avg Raw Score	.23*	.00	.22	-.04	.27*	.01	.13	.08
Avg Cuts	-.08	.01	-.08	.08	-.08	-.09	-.05	-.09
Avg Total Score	.23*	.01	.23*	-.05	.27*	.02	.14	.09
Avg Open Time	-.20	.04	-.19	.25*	-.21	-.17	-.09	-.17
Percent Hits	.19	.27*	.14	-.06	.26*	-.08	.11	.03
Firing Rate	.27*	.08	.26*	-.05	.22	.15	.21	.23*
Hit Proportion	.30**	-.01	.29*	-.08	.37**	-.13	.27*	.09
Hit Rate	.35**	.03	.34**	-.05	.37**	.03	.31**	.21

Note. N = 77.
*p < .05. **p < .01.

Predictor Variables

Correlations among the predictor variables are presented in Table 10. All six of the U-COFT related variables correlated significantly with each other. Moreover, all of the U-COFT related variables except TC computer exercises and TC total exercises correlated significantly with time in crew, the measure of crew turbulence. This suggests that crews that had been together longer had more time to train on U-COFT (since they completed more exercises) and performed better on U-COFT (since they reached a higher crew reticle aim level).

Table 10

Correlations Among Predictor Variables

	TC Computer Exercises	TC Total Exercises	TC Reticle Aim Level	Crew Computer Exercises	Crew Total Exercises	Crew Reticle Aim Level	Time In Crew
1. TC Computer Exercises	1.00						
2. TC Total Exercises	.94*	1.00					
3. TC Reticle Aim Level	.37*	.29*	1.00				
4. Crew Computer Exercises	.76*	.69*	.61*	1.00			
5. Crew Total Exercises	.42*	.42*	.33*	.66*	1.00		
6. Crew Reticle Aim Level	.44*	.34*	.85*	.65*	.33*	1.00	
7. Time in Crew	.22	.20	.34*	.39*	.37*	.38*	1.00

Note. N = 77. TC = Tank Commander

*p < .01.

Relationship Between Performance Measures and Predictor Variables

Correlations between the predictor variables and the performance measures are presented in Table 11. Few of the correlations between the predictor variables and the performance measures were significant. Crew reticle aim level correlated significantly with total score and hit rate, and TC reticle aim level correlated significantly with total score. That is, crews that advanced further in the crew matrix tended to have higher total scores and hit rates on Table VIII. Likewise, crews with TCs that advanced further in the TC matrix tended to have higher total scores. These findings suggest that sustainment training on the U-COFT does train gunnery skills demanded by Table VIII.

Correlations between predictor variables and performance variables were computed separately for day and night tasks and are shown in Tables 12 and 13, respectively. Crew reticle aim level correlated significantly with average total score during both day and night exercises, but TC reticle aim level correlated significantly with average total score only during the day exercises. This latter finding is of minor importance, however, since the correlation between TC reticle aim level and total score differed only sightly

from day to night (r = .26 vs. r = .22). In addition, TC reticle aim level correlated significantly with firing rate during night exercises, but not during day exercises.

Table 11

Correlations Between Table VIII Performance Measures and Predictor Variables

	Table VIII Measure							
Predictor Variable	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
TC Computer Exercises	.12	.13	.11	.11	.01	.11	-.01	.05
TC Total Exercises	.01	.10	.00	.15	-.07	.07	-.08	-.02
TC Reticle Aim Level	.29*	-.07	.30**	-.14	.11	.11	.13	.16
Crew Computer Exercises	.17	.15	.16	.01	.07	.00	.05	.03
Crew Total Exercises	-.07	.22	-.09	.14	.02	-.10	-.12	-.13
Crew Reticle Aim Level	.35**	.01	.35**	-.13	.14	.20	.18	.24*
Time in Crew	-.10	-.01	-.09	.08	-.04	-.13	-.12	-.15

Note. N = 77 for all correlations except those that include the predictor variable time in crew, for which N = 71. TC = Tank commander.
*p < .05. **p < .01.

Table 12

Correlations Between Performance Measures for Table VIII Day Tasks and Predictor Variables

	Table VIII Measure - Day Tasks							
Predictor Variable	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
TC Computer Exercises	.14	.03	.13	.05	.01	.17	-.01	.16
TC Total Exercises	.02	.03	.01	.02	-.08	.16	-.09	.09
TC Reticle Aim Level	.25*	-.09	.26*	-.10	.05	-.01	.14	.10
Crew Computer Exercises	.20	.11	.18	.04	-.01	.02	.05	.08
Crew Total Exercises	.00	.19	-.02	.13	.02	-.02	-.03	-.03
Crew Reticle Aim Level	.26*	.04	.25*	-.11	.02	.13	.09	.17
Time in Crew	-.06	.03	-.06	.14	-.02	-.05	-.05	-.04

Note. N = 77 for all correlations except those that include the predictor variable time in crew, for which N = 71.

Table 13

Correlations Between Performance Measures for Table VIII Night Tasks and Predictor Variables

Predictor Variable	Table VIII Measure - Night Tasks: Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
TC Computer Exercises	.07	.15	.06	.10	.02	.02	-.01	.00
TC Total Exercises	.01	.11	.00	.17	-.03	-.04	-.05	-.05
TC Reticle Aim Level	.22	-.02	.22	-.15	.11	.23*	.07	.17
Crew Computer Exercises	.07	.07	.07	-.05	.10	.05	.03	.02
Crew Total Exercises	-.13	.11	-.14	.04	-.09	-.01	-.21	-.16
Crew Reticle Aim Level	.28*	-.06	.29*	-.10	.21	.20	.19	.21
Time in Crew	-.10	-.08	-.08	.00	-.09	-.13	-.18	-.19

Note. N = 71 for all correlations that include the performance variables average opening time, percent hits, hit proportion, and hit rate except those with the predictor variable time in crew, for which N = 65. N = 72 for all correlations that include the performance variables average raw score, average cuts, and average total score except those with the predictor variable time in crew, for which N = 66. TC = Tank commander.

*p < .05.

Correlations between predictor variables and performance variables were also computed separately for offensive and defensive tasks and are shown in Tables 14 and 15. The correlations for offensive tasks are similar to those obtained with all tasks. That is, TC reticle aim level correlated significantly with raw and total score; and crew reticle aim level correlated

Table 14

Correlations Between Performance Measures for Table VIII Offensive Tasks and Predictor Variables

Predictor Variable	Table VIII Measure - Offensive Tasks: Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
TC Computer Exercises	.13	.18	.12	.11	-.01	.09	.00	.05
TC Total Exercises	.04	.17	.02	.14	-.09	.07	-.04	.00
TC Reticle Aim Level	.29*	.08	.29*	-.15	.17	.14	.14	.19
Crew Computer Exercises	.19	.11	.19	-.02	.06	.02	.03	.06
Crew Total Exercises	-.02	.22	-.02	.12	-.03	-.06	-.06	-.04
Crew Reticle Aim Level	.38**	.06	.38**	-.15	.21	.25*	.19	.27*
Time in Crew	.05	.02	.05	-.06	.02	-.04	-.09	-.09

Note. N = 77 for all correlations except those that include the predictor variable time in crew, for which N = 71. TC = Tank commander.

*p < .05. **p < .01.

Table 15

Correlations Between Performance Measures for Table VIII Defensive Tasks and Predictor Variables

Predictor Variable	Table VIII Measure - Defensive Tasks							
	Avg Raw Score	Avg Cuts	Avg Total Score	Avg Open Time	Percent Hits	Firing Rate	Hit Prop.	Hit Rate
TC Computer Exercises	.08	.00	.08	.04	.02	.09	.01	.07
TC Total Exercises	-.01	-.03	-.01	.07	-.05	.03	-.07	-.01
TC Reticle Aim Level	.16	-.17	.18	-.08	.02	-.01	.10	.08
Crew Computer Exercises	.08	.09	.07	.02	.04	-.02	.07	.03
Crew Total Exercises	-.11	.10	-.13	.10	.04	-.09	-.11	-.11
Crew Reticle Aim Level	.16	-.05	.17	-.06	.02	.02	.12	.10
Time in Crew	-.22	-.04	-.21	.18	-.09	-.22	-.08	-.18

Note. N = 77 for all correlations except those that include the predictor variable time in crew, for which N = 71. TC = tank commander.

significantly with raw score, total score, hit rate, and firing rate. On the other hand, the predictor variables did not correlate significantly with any of the performance measures for defensive tasks.

The finding that the predictor variables correlated significantly with Table VIII performance measures for offensive tasks, but not for defensive tasks, was unexpected. There are two possible explanations for this finding. The first possible explanation is that U-COFT training is more effective at preparing crews for offensive engagements than for defensive engagements. This is unlikely given the fact that there are more defensive than offensive engagements represented in the U-COFT crew matrix. The second possible explanation is that the significant correlation between crew reticle aim level and performance on offensive tasks on Table VIII may be due to the role that target acquisition plays during offensive engagements. Since timing does not begin on defensive tasks until the tanks move out of defilade position, performance scores for defensive tasks primarily reflect marksmanship. Timing on offensive tasks begins as soon as a target appears. Consequently, target acquisition plays a relatively important role in offensive engagements. The significant correlation between U-COFT reticle aim level and offensive tasks, but not defensive tasks, on Table VIII, may reflect the success of U-COFT in training crews to acquire targets.

Predicting Table VIII Performance

The major purpose of this study was to determine whether or not measures of U-COFT performance and crew turbulence could be used to predict which crews would qualify on Table VIII on their first run. The best prediction that could be made without predictor variables is that all 77 crews in the sample would fail to qualify on Table VIII on their first run. Since 24 crews did qualify on their first run, the predictions would be incorrect for 31% of the crews. Thus, predictions made without predictor variables cannot be used to identify the crews that would be most likely to qualify on Table VIII, since

all crews would be predicted to fail Table VIII. The next step in the analysis, therefore, was to try to predict which crews would qualify on Table VIII using the predictor variables.

Regression Analyses

Crew reticle aim level and TC reticle aim level were the only two predictor variables that correlated significantly with average total score on Table VIII. Consequently, scatter plots were constructed of crew reticle aim level and Table VIII total scores (Figure 10) and TC reticle aim level and Table VIII total scores (Figure 11). The regression line shown on each figure (i.e., solid diagonal line) depicts the Table VIII total score that would be predicted using a regression formula. A dotted line drawn horizontally in each figure shows the minimum total score crews must achieve to qualify on Table VIII. In Figure 10, if a vertical line is drawn from the point at which the regression line intersects the dotted line, the vertical line will intercept the X-axis at reticle aim level 39. This indicates that crew reticle aim level cannot be used to predict which crews would qualify on Table VIII. Crews achieving reticle aim levels less than 39 would be expected to fail Table VIII on their first run. Predictions cannot be made among crews reaching reticle aim level 39 since maximum uncertainty concerning passing or failing occurs at that level. In the TC matrix, no crews would be expected to pass since the regression line does not intercept the cutoff score within the established boundary of the matrix. These findings indicate that the individual correlations between crew and TC reticle aim levels and total score are not sufficiently robust to allow prediction of Table VIII performance from reticle aim level alone.

Multiple Regressions

Given that neither crew reticle aim level nor TC reticle aim level could be used to predict which crews would qualify on Table VIII on their first run, the next step was to examine whether multiple predictor composites could improve predictions of Table VIII performance. Multiple regression analyses were conducted to identify predictor variables which, when combined with crew reticle aim level or TC reticle aim level, significantly increased the proportion of variance accounted for in Table VIII average total score. Since progress through the TC and crew matrices should take place at roughly the same rate, variables from the two matrices were expected to have high intercorrelations (which was indeed the case, as reported above). Therefore, prior to the analyses it was decided that no attempts would be made to combine U-COFT predictor variables across matrices. That is, no attempts were made to form predictor composites by combining crew reticle aim level with TC reticle aim level, crew reticle aim level with the number of exercises completed in the TC matrix, or TC reticle aim level with the number of exercises completed in the crew matrix.

The regression analyses showed that there were three cases in which combining a second predictor variable with crew or TC reticle aim level contributed significantly to the prediction of Table VIII total scores. Two of the cases involved crew reticle aim level and the other TC reticle aim level. When combined individually with crew reticle aim level, both time in

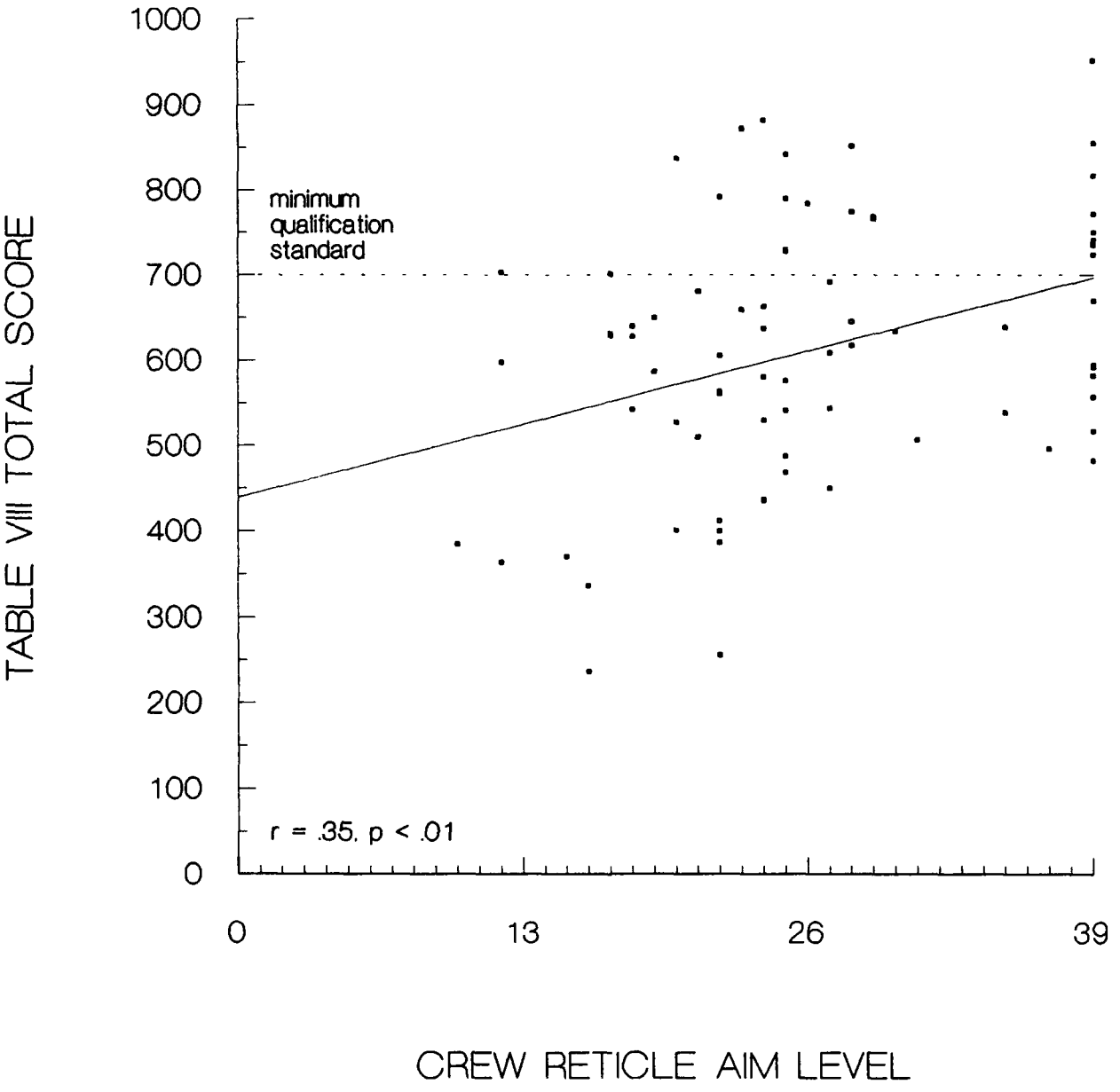

Figure 10. Total score as a function of reticle aim level attained in the U-COFT crew matrix. (Total score = average total score x 10.)

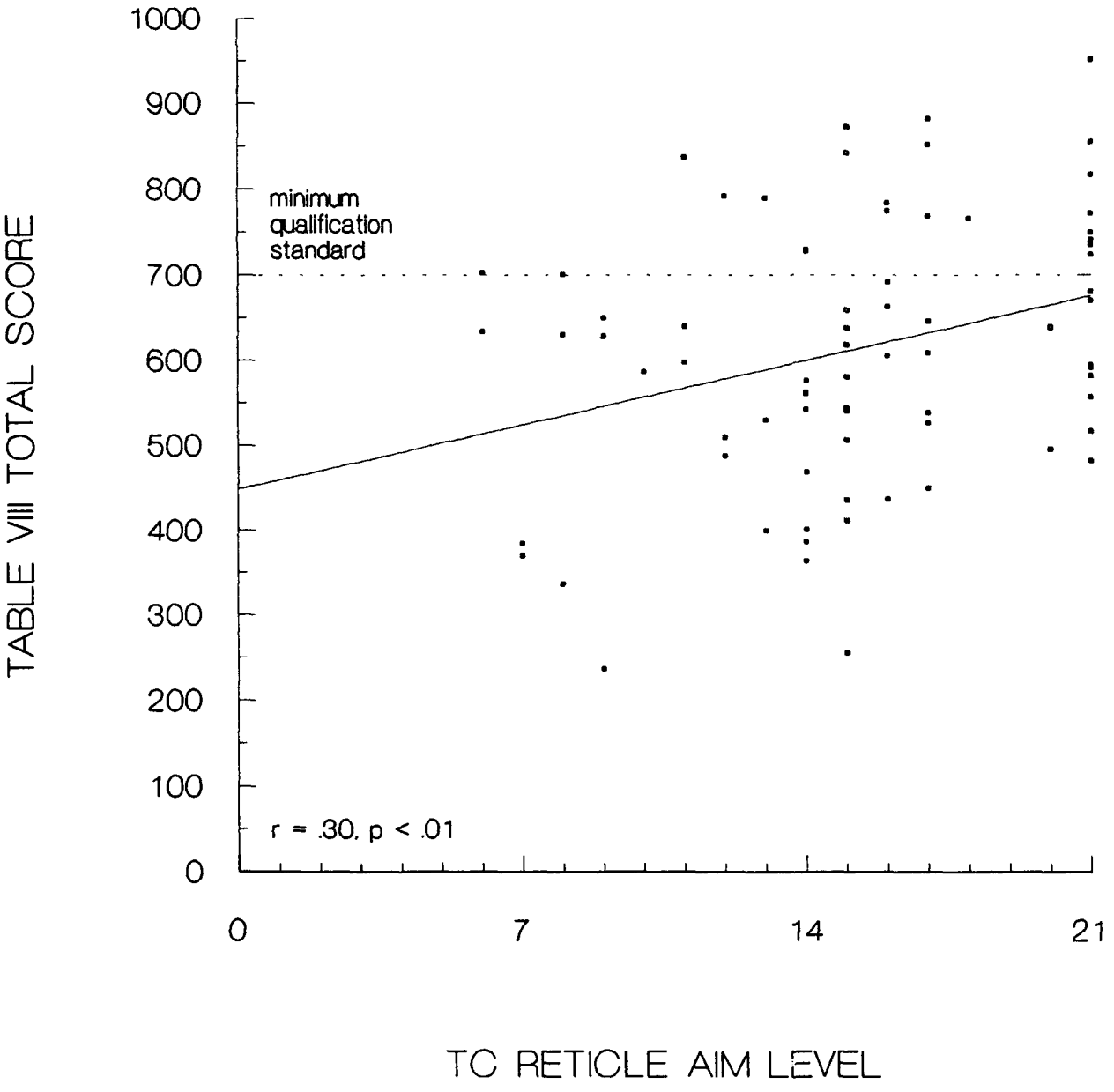

Figure 11. Total score as a function of reticle aim level attained in the U-COFT TC matrix. (Total score = average total score x 10.)

crew and crew total exercises contributed significantly to the prediction of average total score. Likewise, combining time in crew with TC reticle aim level significantly increased the proportion of variance accounted for in average total score. The results of the multiple regression analyses and the increase in proportion of variance accounted for by each of the three composite regression equations are presented in Table 16.

Table 16

Results of Multiple Regression Analyses of Average Total Score by Predictor Variables

Variables Entered in Equation	Multiple R^2	R^2 Change	F	df	p level
Crew reticle aim level	.147				
Crew reticle aim level & Time in crew	.241	.067	5.80	1,68	.05
Overall model	.214		9.26	2,68	.0001
Crew reticle aim level	.125				
Crew reticle aim level & Crew total exercises	.175	.049	4.03	1,68	.05
Overall model	.175		7.77	2,68	.001
TC reticle aim level	.111				
TC reticle aim level & Time in crew	.161	.05	4.05	1,68	.05
Overall model	.161		6.50	2,68	.003

Time in crew and crew total exercises are both weighted negatively in the regression equations in which they appear. Thus, if crews at any given reticle aim level are compared, the crew that had been together the shortest period of time would have the highest predicted total score; and the crew that had been together the longest would have the lowest predicted score. Likewise, at any given reticle aim level the crew that completed the fewest number of U-COFT exercises would have the highest predicted score and the crew that completed the most U-COFT exercises the lowest. The fact that time in crew and the number of U-COFT exercises completed were virtually uncorrelated with average total score (r = .09 for both variables) indicates that they each act as a suppressor variable in their respective regression equations. The variables time in crew and number of U-COFT exercises in effect partial out, or suppress, that part of reticle aim level that is unrelated to average total score. That is, since time in crew and number of U-COFT exercises explain some of the variability in reticle aim level, the proportion of variance in total score explained by reticle aim level is greater.

Accuracy of the predictor equations. The three significant regression equations were used to calculate predicted total scores for each crew. The three resulting predicted scores were individually plotted against each crew's actual total score. Figure 12 shows actual total score plotted against the predicted total score based on crew reticle aim level and time in crew. Figure 13 shows actual total score plotted against the predicted total score calculated from crew reticle aim level and the number of exercises completed

in the crew matrix. Figure 14 shows the plot of actual total score and the predicted total score derived from TC reticle aim level and time in crew. In each figure, the horizontal dotted line shows the total score necessary to qualify on Table VIII and the solid line along the diagonal represents the regression line.

Figure 12 shows that the predictor composite of crew reticle aim level and time in crew predicted that 12 crews would qualify on Table VIII and 65 crews would fail. Of the 12 crews predicted to qualify, only six actually qualified on their first run. In addition, only 47 of the 65 crews that were predicted to fail actually failed to qualify. Thus, 50% of the crews that were predicted to qualify actually qualified, and 72% of the crews that were predicted to fail actually failed. Overall, 53 of the 77 predictions (69%) based on the composite of crew reticle aim level and time in crew were accurate. That is the same level of accuracy that would be achieved if the predictor variables were ignored. However, if predictor variables were not used and all 77 crews were allowed to participate on Table VIII, 31% of the crews (i.e., 24 crews) would qualify. On the other hand, if predictor variables were used and crews had to have a predicted total score of at least 700 to participate on Table VIII, 50% of the crews (i.e., 6 crews) would qualify. Although the number of qualifying crews would be reduced from 24 to 6 by using the predictor composite, the number of crews participating on Table VIII would be reduced from 77 to 12. Of course, all crews would participate on Table VIII when the predictors indicate that they would be likely to qualify.

Figure 13 shows that the regression equation that includes crew reticle aim level and the total number of exercises completed in the crew matrix predicts that 8 crews would qualify and 69 crews would fail. Four of the 8 crews (50%) predicted to qualify actually qualified, and 49 of the 69 crews (71%) predicted to fail actually failed. Again, 53 of the 77 predictions (69%) were correct. These accuracy levels and the passing rate are virtually the same as those obtained using the composite of crew reticle aim level and time in crew. However, the composite of crew reticle aim level and time in crew correctly predicted 25% of the crews that qualified, while the composite of crew reticle aim level and total number of exercises correctly predicted only 17% of the crews that qualified.

Figure 14 shows that the composite of TC reticle aim level and time in crew predicted that five crews would qualify and 72 would fail. Only two of the five crews (40%) predicted to qualify did indeed pass, and 50 of the 72 crews (69%) predicted to fail did indeed fail. Thus, 52 of the 77 predictions (68%) were correct. However, the composite of TC reticle aim level and time in crew was able to predict only two of the 24 crews (3%) that actually qualified.

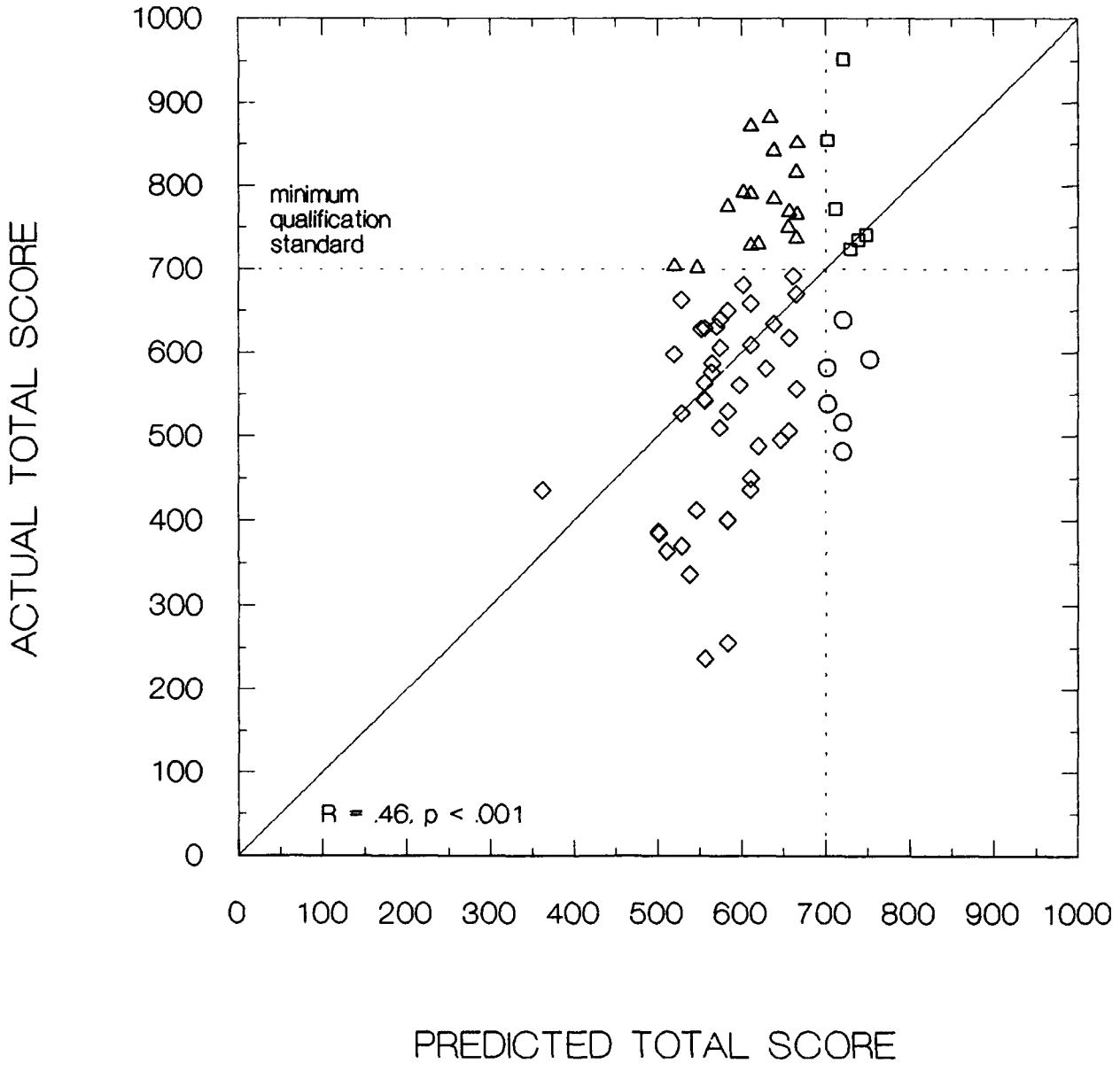

Figure 12. Actual total score plotted against a predicted total score based on crew reticle aim level and time in crew. (Actual total score = average total score x 10. Predicted total score = 419.16 + [9.14 x crew reticle aim level] + [-.921 x time in crew]. Geometric shapes were used as plotting points to assist the reader in identifying the quadrant of the plot in which a point occurred.)

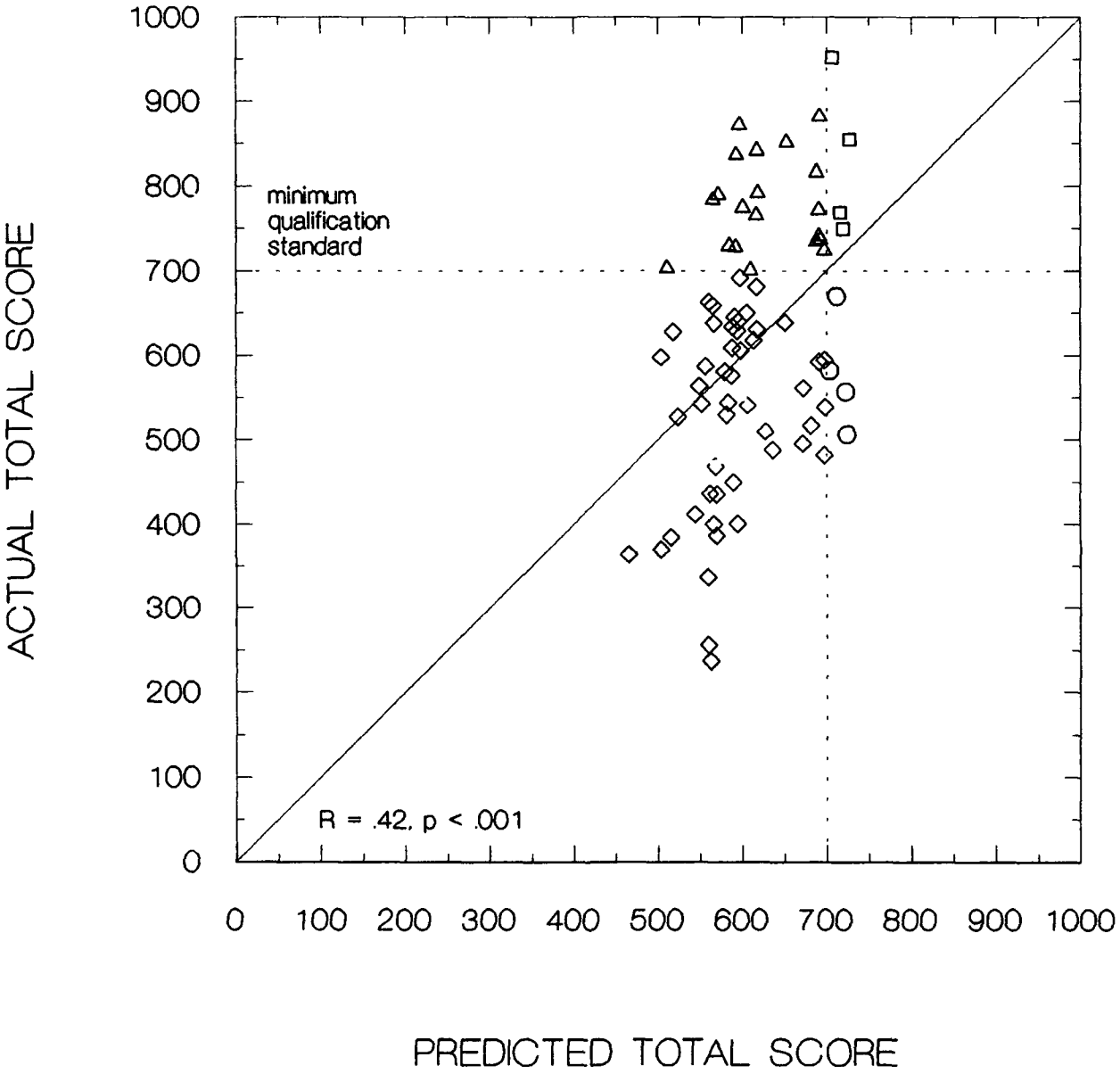

Figure 13. Actual total score plotted against a predicted total score based on crew reticle aim level and the total number of exercises completed in the crew matrix. (Actual total score = average total score x 10. Predicted total score = 504.31 + [8.07 x crew reticle aim level] + [-1.58 x crew total exercises]. Geometric shapes were used as plotting points to assist the reader in identifying the quadrant of the plot in which a point occurred.)

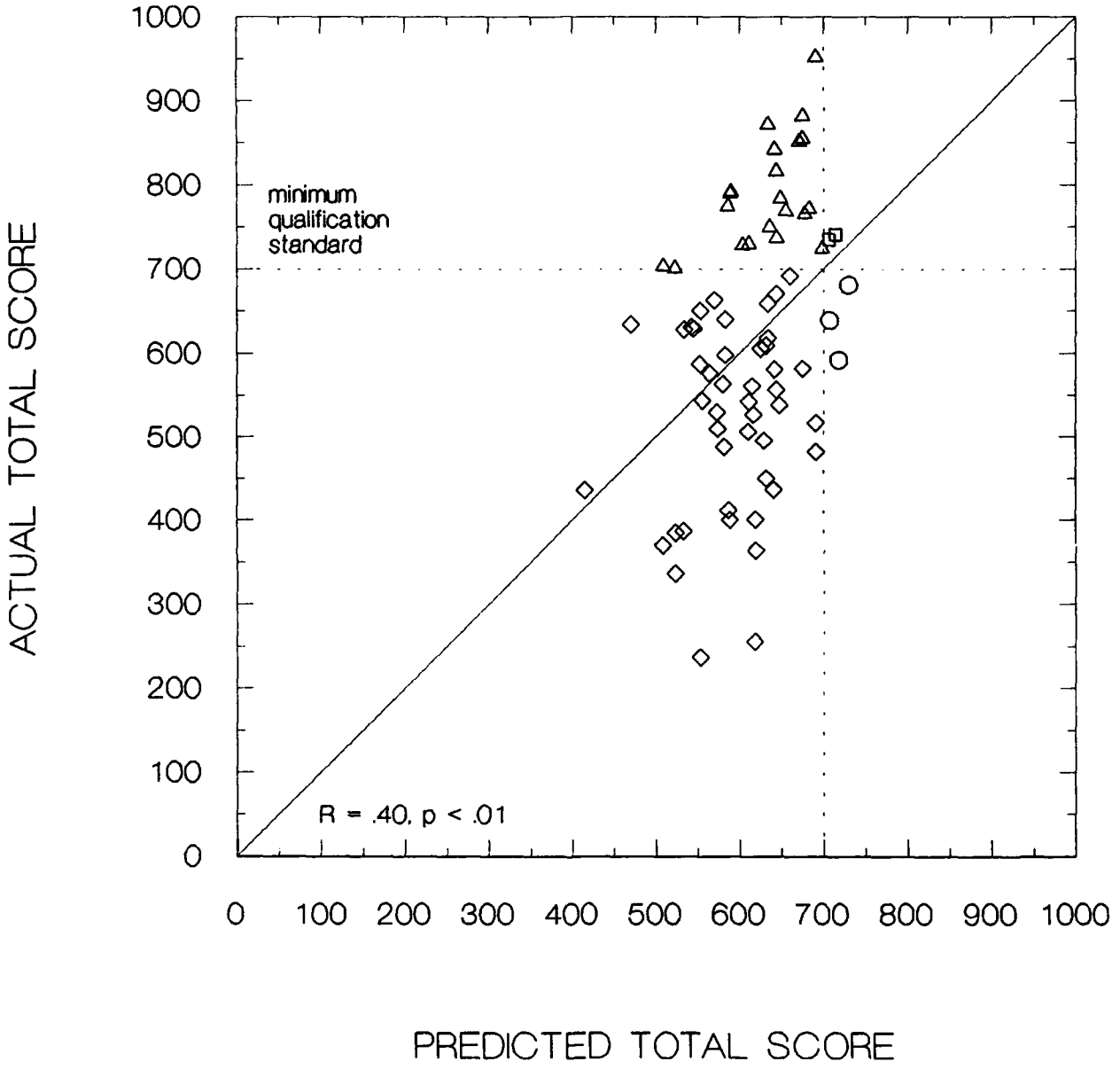

Figure 14. Actual total score plotted against a predicted total score based on TC reticle aim level and time in crew. (Actual total score = average total score x 10. Predicted total score = 428.35 + [14.72 x TC reticle aim level] + [-7.81 x time in crew]. Geometric shapes were used as plotting points to assist the reader in identifying the quadrant of the plot in which a point occurred.)

Table 17 shows the number of correct and incorrect predictions of Table VIII first-run performance as calculated from crew reticle aim level alone and each of the three predictor composites. The table shows that using crew reticle aim level by itself or using any one of the three predictor composites yields approximately the same number of correct (52-53) and incorrect (24-25) predictions. A close examination of Table 15 shows that as the number of true positives (crews predicted to qualify that actually qualified) increases, the number of false positives (crews predicted to qualify that actually failed) increases, and the number of true negatives (crews predicted to fail that actually failed) and false negatives (crews predicted to fail that actually qualified) decreases.

Table 17

Frequency of Correct and Incorrect Predictions of Table VIII First-Run Outcomes

Predictors	Predictions			
	Correct		Incorrect	
	Qualify	Fail	Qualify	Fail
Crew Reticle Aim Level	0	53	0	24
TC Reticle Aim Level & Time in Crew	2	50	3	22
Crew Reticle Aim Level & Crew Total Exercises	4	49	4	20
Crew Reticle Aim Level & Time in Crew	6	47	6	18

Utilizing the regression equations to predict Table VIII scores. Figure 15 shows the expected first-run Table VIII scores as calculated from different combinations of crew reticle aim level and time in crew (in months). According to the figure, crews that reach reticle aim level 32 in the crew matrix would be expected to qualify on their first run on Table VIII, but only if the crew had been paired together for one month or less. Presumably a crew that could reach level 32 in just one month would be good enough to qualify on Table VIII on their first run. As crews are together for increasingly longer periods of time, they would have to attain higher reticle aim levels to be expected to qualify. Crews that reached reticle aim level 39, but had to be together 8-1/2 months to do so, would not be expected to qualify. Thus, the data suggest that crews skilled enough to reach level 32 in one month or less will qualify on their first run on Table VIII, but crews that take longer than eight months to reach level 39 will not. No conclusions can be reached concerning the effects of time in crew on Table VIII performance, however, since the correlation between time in crew and average total score was not significant.

MONTHS PAIRED TOGETHER IN CREW

CREW RETICLE AIM LEVEL	8.5	8.0	7.5	7.0	6.5	6.0	5.5	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5
39	698.1	702.7	707.2	711.8	716.3	720.9	725.5	730.0	734.6	739.1	743.7	748.3	752.8	757.4	761.9	766.5	771.1
38	689.0	693.5	698.1	702.6	707.2	711.8	716.3	720.9	725.4	730.0	734.6	739.1	743.7	748.2	752.8	757.4	761.9
37	679.8	684.4	688.9	693.5	698.1	702.6	707.2	711.7	716.3	720.9	725.4	730.0	734.5	739.1	743.7	748.2	752.8
36	670.7	675.2	679.8	684.4	688.9	693.5	698.0	702.6	707.2	711.7	716.3	720.8	725.4	730.0	734.5	739.1	743.6
35	661.5	666.1	670.7	675.2	679.8	684.3	688.9	693.5	698.0	702.6	707.1	711.7	716.3	720.8	725.4	729.9	734.5
34	652.4	657.0	661.5	666.1	670.6	675.2	679.8	684.3	688.9	693.4	698.0	702.6	707.1	711.7	716.2	720.8	725.4
33	643.3	647.8	652.4	656.9	661.5	666.1	670.6	675.2	679.7	684.3	688.9	693.4	698.0	702.5	707.1	711.7	716.2
32	634.1	638.7	643.2	647.8	652.4	656.9	661.5	666.0	670.6	675.2	679.7	684.3	688.8	693.4	698.0	702.5	707.1
31	625.0	629.5	634.1	638.7	643.2	647.8	652.3	656.9	661.5	666.0	670.6	675.1	679.7	684.3	688.8	693.4	697.9
30	615.8	620.4	625.0	629.5	634.1	638.6	643.2	647.8	652.3	656.9	661.4	666.0	670.6	675.1	679.7	684.2	688.8
29	606.7	611.3	615.8	620.4	624.9	629.5	634.1	638.6	643.2	647.7	652.3	656.9	661.4	666.0	670.5	675.1	679.7
28	597.6	602.1	606.7	611.2	615.8	620.4	624.9	629.5	634.0	638.6	643.2	647.7	652.3	656.8	661.4	666.0	670.5
27	588.4	593.0	597.5	602.1	606.7	611.2	615.8	620.3	624.9	629.5	634.0	638.6	643.1	647.7	652.3	656.8	661.4
26	579.3	583.8	588.4	593.0	597.5	602.1	606.6	611.2	615.8	620.3	624.9	629.4	634.0	638.6	643.1	647.7	652.2
25	570.1	574.7	579.3	583.8	588.4	592.9	597.5	602.1	606.6	611.2	615.7	620.3	624.9	629.4	634.0	638.5	643.1
24	561.0	565.6	570.1	574.7	579.2	583.8	588.4	592.9	597.5	602.0	606.6	611.2	615.7	620.3	624.8	629.4	634.0
23	551.9	556.4	561.0	565.5	570.1	574.7	579.2	583.8	588.3	592.9	597.5	602.0	606.6	611.1	615.7	620.3	624.8
22	542.7	547.3	551.8	556.4	561.0	565.5	570.1	574.6	579.2	583.8	588.3	592.9	597.4	602.0	606.6	611.1	615.7
21	533.6	538.1	542.7	547.3	551.8	556.4	560.9	565.5	570.1	574.6	579.2	583.7	588.3	592.9	597.4	602.0	606.5
20	524.4	529.0	533.6	538.1	542.7	547.2	551.8	556.4	560.9	565.5	570.0	574.6	579.2	583.7	588.3	592.8	597.4
19	515.3	519.9	524.4	529.0	533.5	538.1	542.7	547.2	551.8	556.3	560.9	565.5	570.0	574.6	579.1	583.7	588.3
18	506.2	510.7	515.3	519.8	524.4	529.0	533.5	538.1	542.6	547.2	551.8	556.3	560.9	565.4	570.0	574.6	579.1
17	497.0	501.6	506.1	510.7	515.3	519.8	524.4	528.9	533.5	538.1	542.6	547.2	551.7	556.3	560.9	565.4	570.0
16	487.9	492.4	497.0	501.6	506.1	510.7	515.2	519.8	524.4	528.9	533.5	538.0	542.6	547.2	551.7	556.3	560.8
15	478.7	483.3	487.9	492.4	497.0	501.5	506.1	510.7	515.2	519.8	524.3	528.9	533.5	538.0	542.6	547.1	551.7
14	469.6	474.2	478.7	483.3	487.8	492.4	497.0	501.5	506.1	510.6	515.2	519.8	524.3	528.9	533.4	538.0	542.6
13	460.5	465.0	469.6	474.1	478.7	483.3	487.8	492.4	496.9	501.5	506.1	510.6	515.2	519.7	524.3	528.9	533.4
12	451.3	455.9	460.4	465.0	469.6	474.1	478.7	483.2	487.8	492.4	496.9	501.5	506.0	510.6	515.2	519.7	524.3
11	442.2	446.7	451.3	455.9	460.4	465.0	469.5	474.1	478.7	483.2	487.8	492.3	496.9	501.5	506.0	510.6	515.1
10	433.0	437.6	442.2	446.7	451.3	455.8	460.4	465.0	469.5	474.1	478.6	483.2	487.8	492.3	496.9	501.4	506.0
9	423.9	428.5	433.0	437.6	442.1	446.7	451.3	455.8	460.4	464.9	469.5	474.1	478.6	483.2	487.7	492.3	496.9
8	414.8	419.3	423.9	428.4	433.0	437.6	442.1	446.7	451.2	455.8	460.4	464.9	469.5	474.0	478.6	483.2	487.7

Figure 15. Predicted average total score on Table VIII as a function of time together as a crew and the reticle aim level attained in the U-COFT crew matrix. (The predicted scores within the darkened portion of the matrix fall below the minimum qualification standards for Table VIII.)

Figure 16 shows the expected first-run Table VIII scores derived from different combinations of crew reticle aim level and total number of exercises completed in the U-COFT crew matrix. According to the figure, crews proficient enough to attain level 28 in only 15 exercises are likely to achieve a qualifying score on their first run on Table VIII. The figure also shows that crews failing to reach level 39 in less than 80 exercises will not be expected to qualify on their first run. This suggests that as crews complete additional exercises, they must make progress within the crew matrix in order to be expected to qualify on Table VIII.

Figure 17 shows the expected first-run Table VIII scores as calculated from different combinations of TC reticle aim level and time in crew (months). According to the figure, a crew whose TC has reached reticle aim level 19 in the TC matrix would be expected to qualify on Table VIII, but only if the TC and gunner have been paired together for one month or less. Obviously, if the TC and gunner have been together for one month or less, either the TC, or the gunner, or both are new to the crew or new to their position. If the TC is new, the results suggest that a crew will qualify if the TC is good enough to reach level 19 in the TC matrix in one month or less. As the TC and gunner are together for longer periods of time, the TC would have to attain increasingly higher reticle aim levels for the crew to be expected to qualify. Any crew that has been together for five months or more without the TC attaining reticle aim level 21 of the TC matrix would not be expected to qualify on Table VIII. Presumably, any TC that took five months to reach level 21 is not proficient enough to have his crew qualify on its first run of Table VIII.

Discussion

The performance data revealed that 53 of the 77 tank crews in the sample failed to qualify on their first run on Table VIII. Thus, two-thirds of the tank crews participating on the table had to refire one or more gunnery engagements. This finding confirms the notion that improved ammunition conservation techniques will be needed if ammunition allocations are reduced in the future.

The major purpose of this study was to determine how well performance on Table VIII could be predicted from amount and level of training on U-COFT and from crew turbulence data. If these variables could predict which crews would qualify and which crews would fail to qualify on their first run on Table VIII, then it would be possible to reduce ammunition expenditures by allowing only those crews that would be likely to qualify to participate on Table VIII. The remaining crews would receive additional training on a gunnery trainer or simulator until they too would be expected to qualify on their first run on Table VIII. The savings in ammunition would be achieved by reducing the number of crews that would have to refire the gunnery engagements.

The results of the data analysis showed that two of the predictor variables--crew reticle aim level and TC reticle aim level--correlated significantly with average total score. The correlations were not large (.35 and .30, respectively), however, and neither variable could be used to predict which crews would qualify on their first run on Table VIII. Multiple

TOTAL NUMBER OF EXERCISES COMPLETED IN THE CREW MATRIX

CREW RETICLE AIM LEVEL	80	75	70	65	60	55	50	45	40	35	30	25	20	15
39	692.6	700.5	708.4	716.3	724.2	732.1	740.0	747.9	755.8	763.7	771.6	779.5	787.4	795.3
38	684.6	692.5	700.4	708.3	716.2	724.1	732.0	739.9	747.8	755.7	763.6	771.5	779.4	787.3
37	676.5	684.4	692.3	700.2	708.1	716.0	723.9	731.8	739.7	747.6	755.5	763.4	771.3	779.2
36	668.4	676.3	684.2	692.1	700.0	707.9	715.8	723.7	731.6	739.5	747.4	755.3	763.2	771.1
35	660.4	668.3	676.2	684.1	692.0	699.9	707.8	715.7	723.6	731.5	739.4	747.3	755.2	763.1
34	652.3	660.2	668.1	676.0	683.9	691.8	699.7	707.6	715.5	723.4	731.3	739.2	747.1	755.0
33	644.2	652.1	660.0	667.9	675.8	683.7	691.6	699.5	707.4	715.3	723.2	731.1	739.0	746.9
32	636.2	644.1	652.0	659.9	667.8	675.7	683.6	691.5	699.4	707.3	715.2	723.0	731.0	738.9
31	628.1	636.0	643.9	651.8	659.7	667.6	675.5	683.4	691.3	699.2	707.1	715.0	722.9	730.8
30	620.0	627.9	635.8	643.7	651.6	659.5	667.4	675.3	683.2	691.1	699.0	706.9	714.8	722.7
29	611.9	619.8	627.7	635.6	643.5	651.4	659.3	667.2	675.1	683.0	690.9	698.8	706.7	714.6
28	603.9	611.8	619.7	627.6	635.5	643.4	651.3	659.2	667.1	675.0	682.9	690.8	698.7	706.6
27	595.8	603.7	611.6	619.5	627.4	635.3	643.2	651.1	659.0	666.9	674.8	682.7	690.6	698.5
26	587.7	595.6	603.5	611.4	619.3	627.2	635.1	643.0	650.9	658.8	666.7	674.6	682.5	690.4
25	579.7	587.6	595.5	603.4	611.3	619.2	627.1	635.0	642.9	650.8	658.7	666.6	674.5	682.4
24	571.6	579.5	587.4	595.3	603.2	611.1	619.0	626.9	634.8	642.7	650.6	658.5	666.4	674.3
23	563.5	571.4	579.3	587.2	595.1	603.0	610.9	618.8	626.7	634.6	642.5	650.4	658.3	666.2
22	555.5	563.4	571.3	579.2	587.1	595.0	602.9	610.7	618.7	626.6	634.5	642.4	650.2	658.2
21	547.4	555.3	563.2	571.1	579.0	586.9	594.8	602.7	610.6	618.5	626.4	634.3	642.2	650.1
20	539.3	547.2	555.1	563.0	570.9	578.8	586.7	594.6	602.5	610.4	618.3	626.2	634.1	642.0
19	531.2	539.1	547.0	554.9	562.8	570.7	578.6	586.5	594.4	602.3	610.2	618.1	626.0	633.9
18	523.2	531.1	539.0	546.9	554.8	562.7	570.6	578.5	586.4	594.3	602.2	610.1	618.0	625.9
17	515.1	523.0	530.9	538.8	546.7	554.6	562.5	570.4	578.3	586.2	594.1	602.0	609.9	617.8
16	507.0	514.9	522.8	530.7	538.6	546.5	554.4	562.3	570.2	578.1	586.0	593.9	601.8	609.7
15	499.0	506.9	514.8	522.7	530.6	538.5	546.4	554.3	562.2	570.1	578.0	585.9	593.8	601.7
14	490.9	498.8	506.7	514.6	522.5	530.4	538.3	546.2	554.1	562.0	569.9	577.8	585.7	593.6
13	482.8	490.7	498.6	506.5	514.4	522.3	530.2	538.1	546.0	553.9	561.8	569.7	577.6	585.5
12	474.8	482.7	490.6	498.5	506.4	514.3	522.1	530.0	537.9	545.9	553.8	561.7	569.6	577.5
11	466.7	474.6	482.5	490.4	498.3	506.2	514.1	522.0	529.9	537.8	545.7	553.6	561.5	569.4
10	458.6	466.5	474.4	482.3	490.2	498.1	506.0	513.9	521.8	529.7	537.6	545.5	553.4	561.3
9	450.5	458.4	466.3	474.2	482.1	490.0	497.9	505.8	513.7	521.6	529.5	537.4	545.3	553.2
8	442.5	450.4	458.3	466.2	474.1	482.0	489.9	497.8	505.7	513.6	521.5	529.4	537.3	545.2

Figure 16. Predicted average total score on Table VIII as a function of the total number of exercises completed and reticle aim level attained in the U-COFT crew matrix. (The predicted scores within the darkened portion of the matrix fall below the minimum qualification standards for Table VIII.)

MONTHS PAIRED TOGETHER IN CREW

RETICLE AIM	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5
21	698.4	702.3	706.2	710.1	714.0	717.9	721.9	725.8	729.7	733.6
20	683.7	687.6	691.5	695.4	699.3	703.2	707.1	711.0	714.9	718.8
19	669.0	672.9	676.8	680.7	684.6	688.5	692.4	696.3	700.2	704.1
18	654.3	658.2	662.1	666.0	669.9	673.8	677.7	681.6	685.5	689.4
17	639.6	643.4	647.4	651.3	655.2	659.1	663.0	666.9	670.8	674.7
16	624.8	628.7	632.6	636.5	640.4	644.3	648.3	652.2	656.1	660.0
15	610.1	614.0	617.9	621.8	625.7	629.6	633.5	637.4	641.3	645.2
14	595.4	599.3	603.2	607.1	611.0	614.9	618.8	622.7	626.6	630.5
13	580.7	584.6	588.5	592.4	596.3	600.2	604.1	608.0	611.9	615.8
12	565.9	569.8	573.8	577.7	581.6	585.5	589.4	593.3	597.2	601.1
11	551.2	555.1	559.0	562.9	566.8	570.7	574.7	578.6	582.5	586.4
10	536.5	540.4	544.3	548.2	552.1	556.0	559.9	563.8	567.7	571.6
9	521.8	525.7	529.6	533.5	537.4	541.3	545.2	549.1	553.0	556.9
8	507.1	511.0	514.9	518.8	522.7	526.6	530.5	534.4	538.3	542.2
7	492.3	496.2	500.2	504.1	508.0	511.9	515.8	519.7	523.6	527.5
6	477.6	481.5	486.4	489.3	493.2	497.1	501.1	505.0	508.9	512.8

Figure 17. Predicted average total score on Table VIII as a function of time together as a crew and the reticle aim level attained in the U-COFT TC matrix. (The predicted scores within the darkened portion of the matrix fall below the minimum qualification standards for Table VIII.)

correlations using two variable composites resulted in higher correlations than were obtained using single predictors. The multiple correlation between average total score and the composite of crew reticle aim level and time in crew, for example, was .46.

Although the correlation with average total score increased when using a composite of two predictor variables, a more important issue concerns the practical consequence of the relationship between the predictor and performance variables. If the crews in the sample had been required to attain an expected total score of 700 before being allowed to fire Table VIII, only twelve crews would have participated in the table without receiving additional training. Half of the twelve crews would have qualified, and half would have failed to qualify. On the other hand, if all of the crews in the sample were allowed to fire regardless of the expected outcome, only 31% would have qualified and 69% would have failed to qualify on Table VIII. Thus, using the predictor variables to determine which crews would be allowed to fire Table VIII would have increased the percentage of crews that qualified from 31% to 50% and would have decreased the percentage of crews that failed to qualify from 69% to 50%. To achieve this increase in efficiency, however, 18 crews that actually qualified on Table VIII would not have been allowed to participate on the table until they attained higher reticle aim levels in the U-COFT crew matrix. Although these 18 crews would have had to take part in more U-COFT exercises, there would be no increase in the number of rounds of live ammunition they would eventually fire. In return for having to provide additional U-COFT training for 18 crews, 47 other crews would have been

prevented from participating on Table VIII when they would have failed to qualify.

By selecting a predicted score of 700 as the prerequisite for firing Table VIII, twelve crews would have been allowed to fire and half of them would have qualified. This level of accuracy is expected since predicted performance scores derived from regression equations deviate from actual scores. The regression lines in Figures 6-9 represent the predicted scores on Table VIII given different levels of U-COFT training and different levels of crew turbulence. The actual scores would be distributed around the regression line with half of the scores being above the line and half of the scores being below the line. Thus, an accuracy level of 50% (i.e., half of the crew pass and half of the crews fail) would be expected when a predicted total score of 700 is used to determine which crews would take part on Table VIII. One way to increase the accuracy of the prediction would be to require a higher predicted score in order to take part on Table VIII. For example, if a predicted total score of 800 were used instead of 700, more than half of the crews would be expected to qualify on Table VIII. Unfortunately, this procedure could not have been used on the present sample since none of the crews had an expected score that high. In fact, using the highest U-COFT level (level 39 in the crew matrix) in the regression equation along with the minimum time in crew (0 months) yields an expected average score of only 775[2]. Consequently, 50% accuracy in predicting which crews would qualify on their first run on Table VIII represents the highest level of accuracy that can be achieved using the predictor variables that were examined in the study. Nevertheless, an accuracy level of 50% is considerably better than an accuracy level of 31% that would be achieved without using any predictors at all.

In summary, if predictor variables were used to determine which crews would be allowed to fire Table VIII, fewer crews would participate on Table VIII until receiving additional training. By delaying their first run on Table VIII, the percentage of crews firing Table VIII that would qualify on their first run would increase from 31% to 50%. Although this procedure would delay participation on Table VIII for most crews, the number of engagements that would have to be refired would be reduced, and there would be a corresponding savings in ammunition.

The basic presumption underlying this research is that additional U-COFT training would be provided to crews expected to fail Table VIII on their first run. The purpose of this additional training would be to allow the crews to progress through the U-COFT matrix. Unfortunately, the additional training could overtax U-COFT facilities that may already be overburdened. Blocks of U-COFT time would have to be reserved for crews needing additional training prior to Table VIII. Although U-COFT plays an important role in sustaining gunnery skills, trainers may have to establish a set of priorities for determining who would have access to U-COFT when the demands for U-COFT time exceed availability. Since it would be highly cost effective to use U-COFT to increase the first-run qualification rate on Table VIII, it would be

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[2]Although the maximum average Table VIII score is actually 1000, the estimates provided by regression formulas always move closer to the mean.

reasonable to expect that preparation for Table VIII would receive a high priority.

Finally, the reader should be aware of a statistical artifact that could lead to erroneous conclusions concerning the relationship of Table VIII performance to either time in position or the number of exercises completed in the crew matrix. The predicted average total scores for Table VIII that were shown in Figures 15, 16, and 17 appear to suggest that crews will not qualify on their first run if the TC and gunner are paired together in the same crew for more than 8 months (see Figure 15), if the crew completed more than 75 exercises in the crew matrix (see Figure 16), or if the TC and gunner are paired together in the same crew for more than 4.5 months (see Figure 17). These conclusions would be inaccurate since they would be based on a statistical artifact. The multiple regression equations used to derive the three figures assume that the predictor variables are without limits. In reality, there are caps on reticle aim level since the crew matrix contains only 39 levels and the TC matrix contains only 21 levels. Therefore, any conclusions concerning crews that have been together for relatively long periods of time or that have completed a relatively high number of U-COFT exercises (which, in turn, is a function of the time the crew has been together) could be misleading.

PHASE II

Method

Participants

Phase II utilized Table VIII, U-COFT, and crew turbulence data collected from four M1 tank battalions (136 crews) in two CONUS divisions.

Predictor Variables

The only predictor variables included in the Phase II analyses were crew reticle aim level and time in crew. Data pertaining to the remaining predictor measures utilized in Phase I (i.e., TC and crew computer exercises, TC and crew total exercises, and TC reticle aim level) were unavailable for the majority of the crews.

Performance Variables

Average total score on Table VIII was the only performance measure included in the analysis of the data collected for Phase II. The other four measures of overall performance used in Phase I (average raw score, average cuts, average opening time, and percent hits) and the three measures of main gun performance (firing rate, hit proportion, and hit rate) were dropped because data concerning those variables were unavailable for most of the crews.

Analyses

Descriptive Statistics

Summary statistics and distributions were calculated for the following: (a) measures summarizing first-run performance on Table VIII; (b) measures summarizing performance on the major portions of Table VIII (i.e., separate summary statistics for day tasks, night tasks, offensive tasks, and defensive tasks); and (c) summaries of the predictor variables (crew reticle aim level and crew turbulence).

Intercorrelations and Correlations

The following intercorrelations were obtained: (a) intercorrelations among the predictor variables, (b) intercorrelations among the performance measures, and (c) correlations between the predictor variables and the performance measures.

Cross-Validation of Phase I Findings

The model derived from the regression analyses conducted during Phase I was used to predict the Table VIII performance of the Phase II crews. These predicted scores were then plotted against actual scores to determine the cross-validity of the predictor equation.

Replication of Phase I Regression Analyses

The regression analyses conducted during Phase I were replicated to determine if assigning different weights to the variables in the regression equation would increase the validity of the model as applied to the data collected for Phase II.

Results

Descriptive Statistics

Table VIII Performance Measures

Summary statistics and distributions. The summary statistics for Table VIII average total score are shown in Table 18. The mean average total score of 74.2 results in a mean total score of 742.0 (i.e., average total score multiplied by 10) which is well above the minimum score of 700 necessary for crew qualification on Table VIII, and is 130 points greater than the mean total score for the Phase I crews. In addition, although the distribution of total scores for the Phase I crews (Figure 2) was roughly normal, the distribution of total scores for the Phase II crews, as presented in Figure 18, is negatively skewed. That is, the scores are clustered towards the high end of the performance range.

Table 18

Summary Statistics for Average Total Score on Table VIII and Its Major Portions

	Average Total Score	Major Portions of Table VIII			
		Day	Night	Offense	Defense
Minimum	22.20	21.17	0.00	7.00	20.00
Maximum	96.60	100.00	100.00	100.00	99.40
Mean	74.20	69.78	80.84	72.78	74.22
S.D.	15.14	17.56	19.75	22.85	15.99

Note. N = 136.

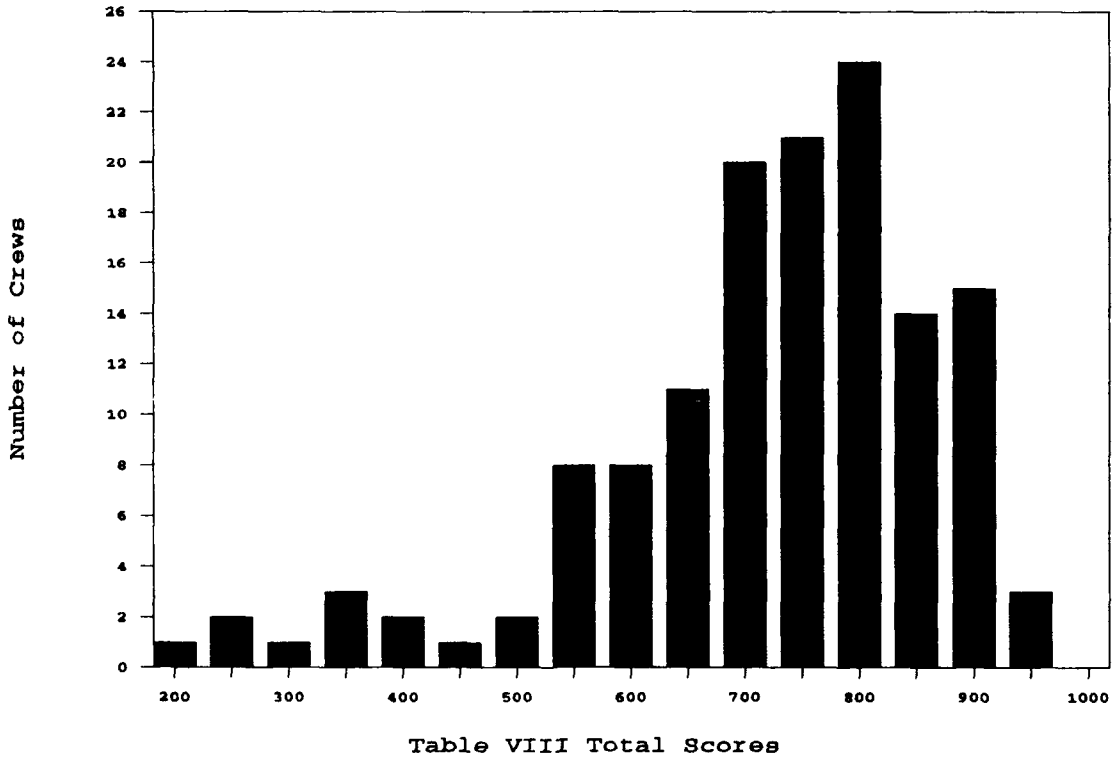

Figure 18. Distribution of Table VIII total scores (average total score multiplied by 10).

Because of the large discrepancy in mean total score between the crews in Phase I and Phase II, performance on Table VIII was broken down by battalion for both the Phase I and Phase II crews. The summary statistics presented in Table 19 show that performance on Table VIII was not consistent across battalions in either phase, as mean total scores ranged from 530.2 to 685.5 in Phase I and from 647.9 to 830.4 in Phase II.

Table 19

Summary Statistics for Table VIII Average Total Score by Phase and Battalion

	Phase I Battalions		Phase II Battalions			
	1	2	1	2	3	4
n:	41	36	19	38	35	44
Minimum	43.60	23.70	25.50	56.70	22.20	44.40
Maximum	95.20	83.70	95.60	95.40	91.90	96.60
Mean	68.55	53.02	66.56	83.04	64.79	77.36
S.D.	11.98	14.65	19.39	8.47	15.85	11.18

Performance on the Major Portions of Table VIII

Summary statistics for average total score on Table VIIIA (day), Table VIIIB (night), Table VIII offensive tasks, and Table VIII defensive tasks are presented in Table 18.

Day versus night. Average total score on Table VIII was significantly higher for tasks fired at night for those fired during the day ($F[1,135] = 35.795$, $p < .01$). This relationship is opposite the one found in the Phase I analysis. The Phase II mean night score is 11 points higher than the mean day score, while the Phase I mean night score is 21 points lower than the mean day score.

Offense versus defense. A comparison of the mean average total scores for the offensive and defensive tasks revealed no significant differences. This parallels the results of the Phase I analysis, although the Phase II total scores are higher than the Phase I total scores for both the offensive (10 points) and defensive (14 points) tasks.

Predictor Variables

Summary statistics and distributions. The 136 crews in Phase II attained a mean reticle aim level of 20.80 in the crew matrix, with a standard deviation of 8.33. Figure 19 shows the distribution of crew reticle aim level for the Phase II crews. A comparison of the means for the Phase I (mean = 26.29) and Phase II samples reveals that the Phase II crews did not progress as far in the matrix as the crews in Phase I. The average crew in Phase II had reached reticle aim group 3 in the crew matrix, whereas the average Phase I crew had reached reticle aim group 4.

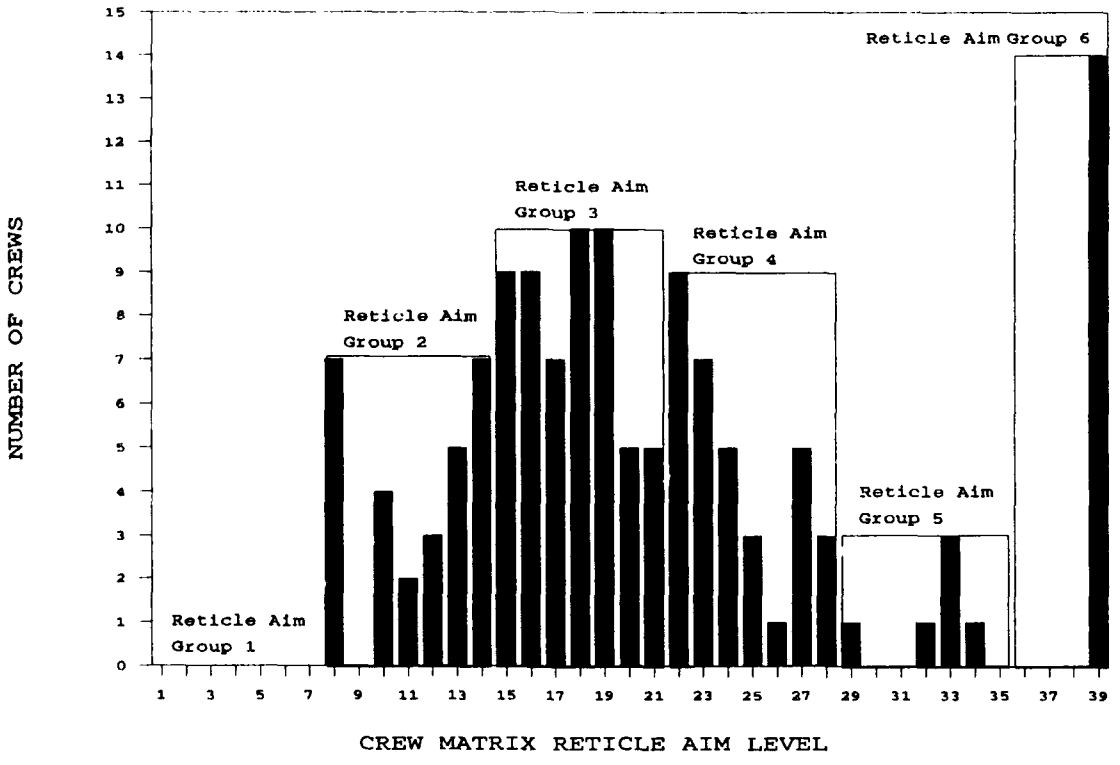

Figure 19. Distribution of crew matrix reticle aim level and reticle aim group.

Data regarding the amount of time crews had been paired together were available for 129 of the Phase II crews. The length of time crews in Phase II had been together ranged from 2 weeks to 33 months with a mean of 4.68 months, and a standard deviation of 5.79. The distribution of time in crew for Phase II, as shown in Figure 20, is similar to that for Phase I and again the median (2 months) is probably a better indicator of crew turbulence than is the mean. Only 50% of the Phase II crews were together longer than 2 months, 31% longer than 3 months, 22% longer than 6 months, and 9% longer than 1 year.

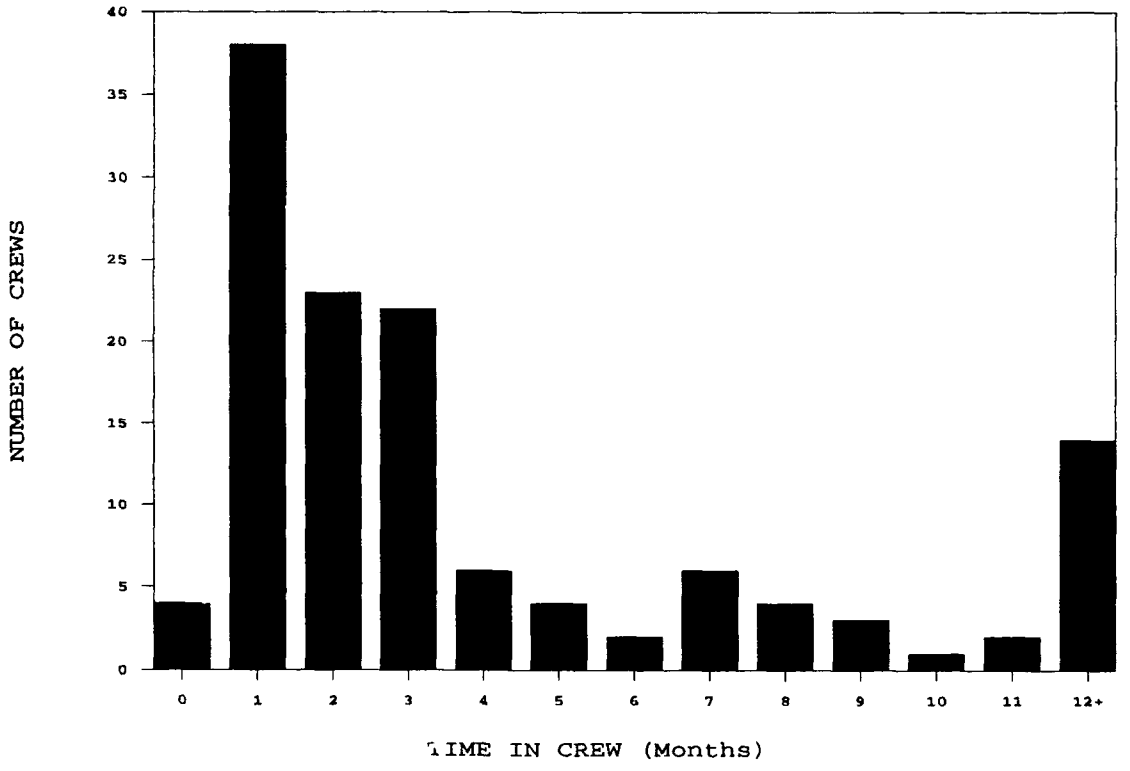

Figure 20. Distribution of time in months that the TC and gunner had been paired together.

Intercorrelations and Correlations

Table 20 shows the intercorrelations among average total score on Table VIII, average total score on each of the major portions of Table VIII, U-COFT crew reticle aim level, and time in crew.

Table 20

Correlations Among Table VIII Performance Measures

	Average Total Score					Crew Reticle Aim Level	Time in Crew
	Table VIII	Day	Night	Offense	Defense		
1. Avg Total Score - Table VIII	1.00						
2. Avg Total Score - Day	.87**	1.00					
3. Avg Total Score - Night	.75**	.34**	1.00				
4. Avg Total Score - Offense	.78**	.68**	.59**	1.00			
5. Avg Total Score - Defense	.81**	.74**	.58**	.39**	1.00		
6. Crew Reticle Aim Level	.10	.05	.12	.09	.04	1.00	
7. Time in Crew	.22*	.21*	.15	.20*	.15	.46**	1.00

Note. N = 136 for all correlations except those that include the predictor variable time in crew, for which N = 129.

*$p < .05$. **$p < .01$.

Table VIII Performance Measures

Average total scores on the major portions of Table VIII were all highly intercorrelated with each other and with Table VIII as a whole. Although the lowest of these correlations were between scores on day and night tasks (r = .34) and scores on offensive and defensive tasks (r = .39), these correlations were statistically significant.

Predictor Variables

The correlation between crew reticle aim level and time in crew (r = .39) was significant and is comparable to the correlation between those same variables that was obtained in Phase I (r = .38).

Relationship Between Performance Measures and Predictor Variables

Crew reticle aim level was not significantly correlated with average total score on Table VIII or any of its major portions. This is in sharp contrast to the Phase I findings in which crew reticle aim level was significantly related to average total score on Table VIII as a whole (r = .35), day tasks (r = .25), night tasks (r = .29), and offensive tasks (r = .38).

Time in crew was significantly correlated with average total score on Table VIII (r = .22), day tasks (r = .21), and offensive tasks (r = .20). Once again, these relationships are markedly different from those found during Phase I, where time in crew was not significantly correlated with any of the performance measures.

Cross-Validation of Phase I Findings

The regression equation based on the composite of crew reticle aim level and time in crew that was derived in Phase I was used to predict total score on Table VIII for each of the Phase II crews. The correlation between predicted score and actual score was not significant (r = -.06) and did not approach the correlation obtained during the Phase I analyses (r = .46). Figure 21 depicts actual total score plotted against predicted total score based on the Phase I prediction equation. The number of correct and incorrect predictions with regards to crews meeting the minimum qualification score of 700 are shown in Table 21. Only 29% of the predictions were accurate. Of the inaccurate predictions, 70% were false negatives (crews predicted to fail that actually passed), and 1% were false positives (crews predicted to pass that actually failed). These results suggest that the model derived during Phase I appears to be applicable only to the sample on which it was based.

Table 21

Frequency of Correct and Incorrect Predictions of Table VIII First-Run Outcomes for Cross-Validation Sample

	Predicted to fail	Predicted to pass	Total
Actual failed	33	2	35
Actual passed	89	5	94
Total	122	7	129

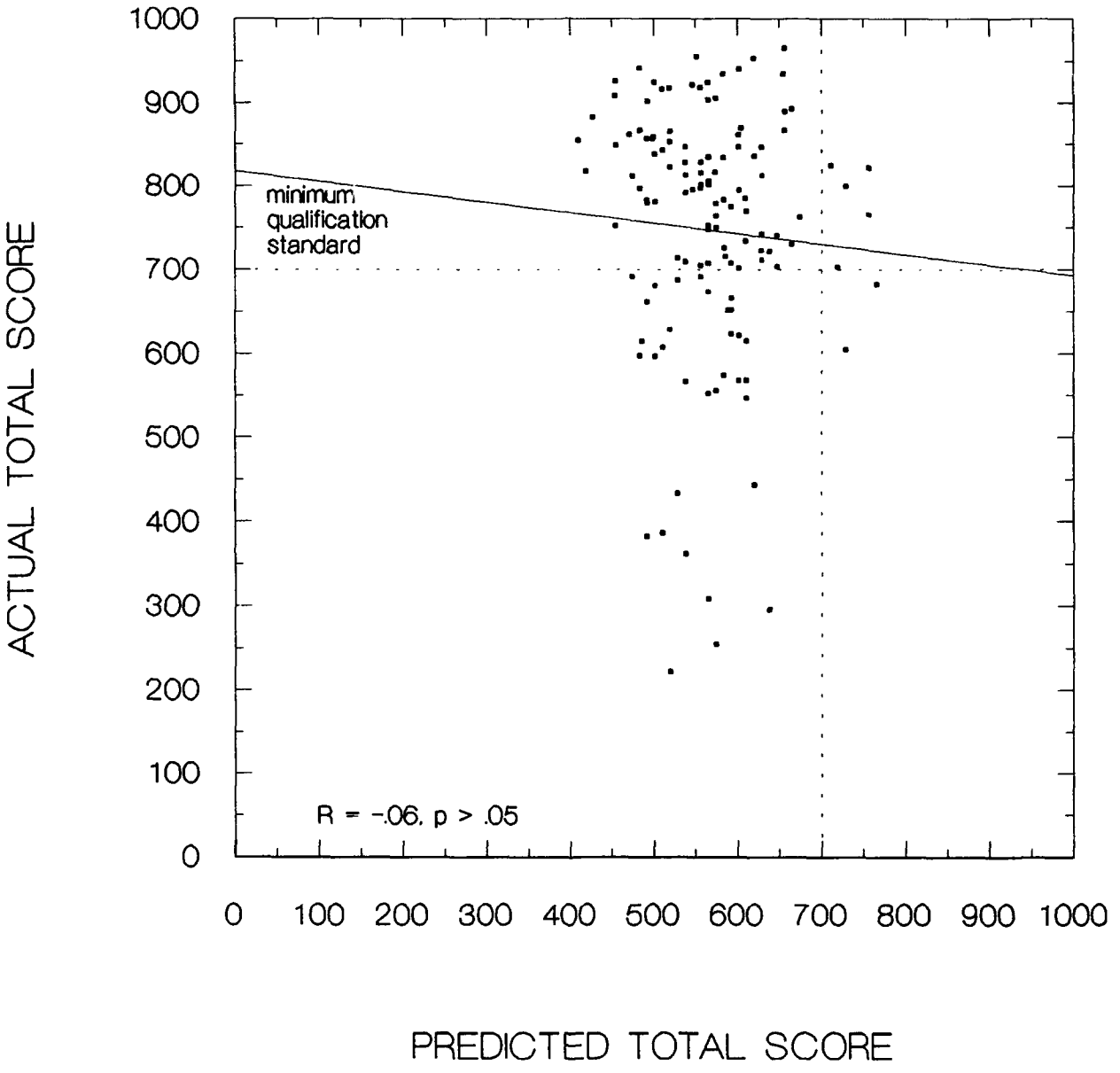

Figure 21. Actual total score for Phase II crews plotted against predicted total score, which was calculated from the regression equation derived from the Phase I sample. (Actual total score = average total score x 10. Predicted total score = 419.16 + [9.14 x crew reticle aim level] + [-9.21 x time in crew]).

Replication of Phase I Findings

Regression Analyses

The same procedures used to derive the prediction equation in Phase I were followed in an attempt to develop a model for predicting Table VIII performance of the crews in Phase II. Time in crew was the only predictor measure to be significantly correlated with total scores on Table VIII. Figure 22 shows a scatter plot of those two variables. The regression line in Figure 22 indicates that time in crew by itself cannot be used to predict whether or not crews will qualify on Table VIII on their first run because the regression line does not intercept the dotted minimum line used to represent the minimum score needed to qualify. As shown in Figure 23, when time in crew is used to predict Table VIII total score, all of the crews are predicted to qualify. Although this results in a prediction accuracy rate of 73% (94 out of 129 crews actually qualified), there is no practical reason for using time in crew as a predictor since all crews would be allowed to fire Table VIII, which is currently the practice.

Multiple Regression Analyses

Since time in crew alone could not be used to predict first-run Table VIII scores, the next step was to determine if adding crew reticle aim level to the regression equation could improve the predictions. The results of the multiple regression analyses are shown in Table 22. Although the equation that incorporates time in crew and crew reticle aim level is significant, the addition of crew reticle aim level to the equation does not increase the proportion of variance accounted for in average total score.

Table 22

Results of Multiple Regression Analyses of Average Total Score by Predictor Variables

Variables Entered in Equation	Multiple R^2	R^2 Change	F	df	p level
Time in crew	.049				
Time in crew & Crew reticle aim level	.049	.000			
Overall Model	.049		3.24	2,127	.043

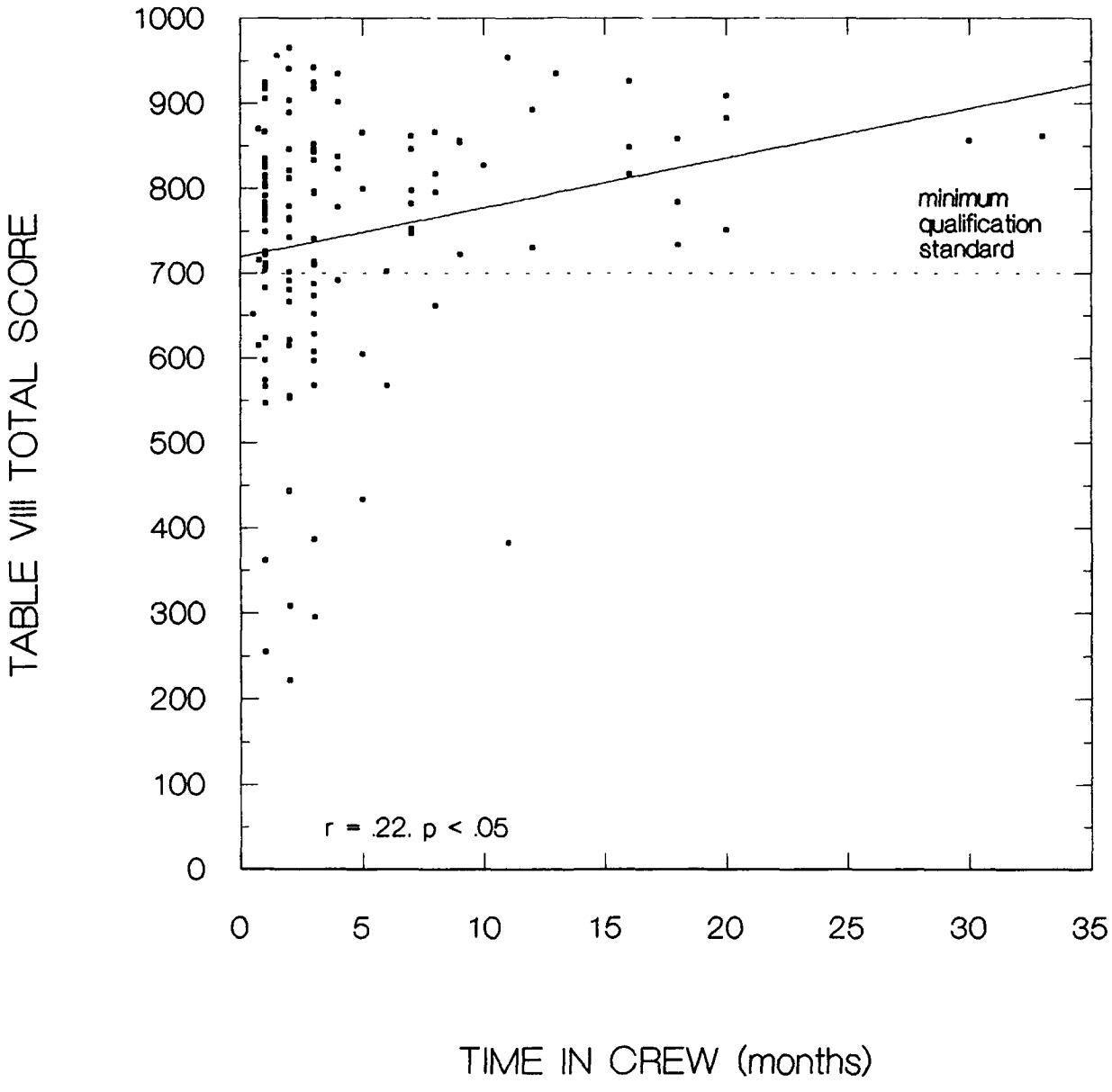

Figure 22. Total score as a function of the number of months TC and gunners had been paired together. (Total score = average total score x 10.)

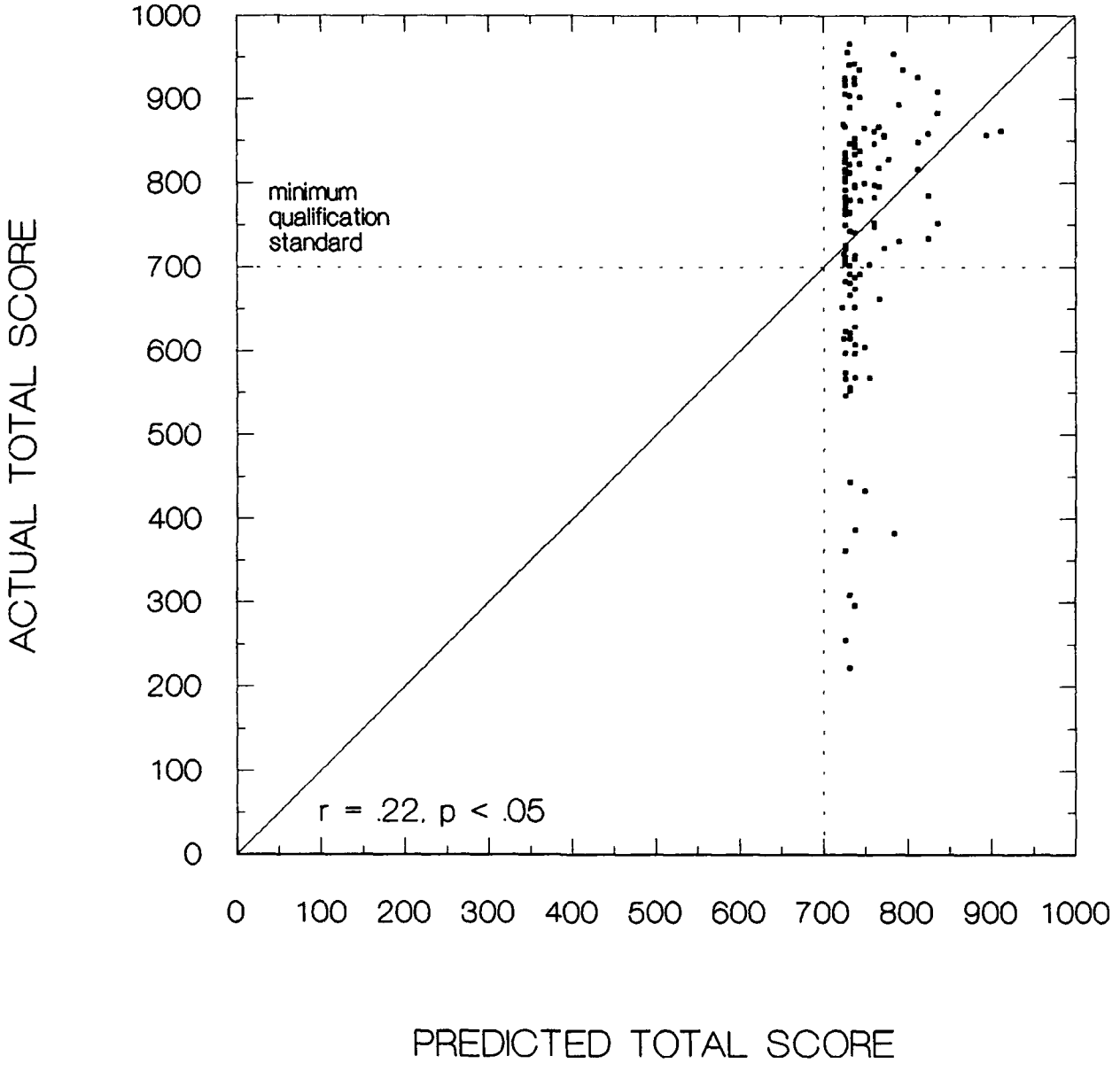

Figure 23. Actual total score plotted against a predicted total score based on time in crew. (Actual total score = average total score x 10. Predicted total score = 71.967 + [.581 x time in crew]).

Discussion

The results obtained during Phase II of the research failed to support the finding from Phase I that Table VIII performance can be predicted from U-COFT performance level and time in crew. Crew reticle aim level and time in crew accounted for 21% of the Table VIII total score variance in Phase I. The same two predictor variables accounted for only 5% of the variance in Phase II. Moreover, the entire 5% was accounted for by time in crew.

The discrepancies between the two sets of findings can be attributed to differences in the predictor variables, differences in the performance measures, or differences in the relationship between the predictor variables and the performance measures. The possible effects of each set of factors are discussed below.

Predictor Variables

Crews participating in Phase I of the research attained a higher crew reticle aim level on U-COFT, on the average, than crews participating in Phase II. Level 26, the average level attained in Phase I, is in crew reticle aim group 4, which provides practice in firing at moving targets. Level 20, the average level achieved in Phase II, is in crew reticle aim group 3, which provides practice in firing at stationary targets. Reticle aim group 2 (the starting point in the matrix for crews in sustainment training) also provides practice firing at stationary targets. As a consequence of the difference in the reticle aim level attained during the two phases of the research, fewer crews received U-COFT training for moving targets during Phase II than during Phase I. As a result, the relationship between U-COFT and Table VIII performance could have been attenuated during Phase II. This may account for the discrepancy in the findings obtained during the two phases of the research.

Restriction of range in any of the predictor variables included in the predictor model could also cause the multiple correlation between the predictors and Table VIII total score to be lowered. This does not appear to be a factor in this research, however. Although the means for crew reticle aim level and time in crew are different for Phase I than for Phase II, the variance and distributions for those variables are approximately equal.

Performance Measures

Crews participating in Phase II of the research obtained a higher average total score on their first run on Table VIII (742.0) than crews participating in Phase I (612.9). The difference in mean total score between the Phase I and Phase II crews could have been due to unit differences in Table VIII performance, a phenomenon that had been reported by Hoffman (1989). Six different battalions participated in the present research--two battalions in Phase I and four battalions in Phase II. The two battalions that participated in Phase I and one of the four battalions that participated in Phase II were from the same CONUS division, and the remaining three battalions that participated in Phase II were from a different CONUS division. The three battalions that were from the division that participated in both Phases scored an average of 623.3 on their first run on Table VIII, whereas the three

battalions from the division that participated only in Phase II scored an average of 754.4 on their first run on Table VIII. This suggests that samples in the two Phases were not equivalent in their performance on Table VIII. The difference in Table VIII performance could have been due to differences between the divisions in the capability of the crews, the experience of the crews, emphasis given to training for Table VIII, or to other factors. Because of the differences between the two divisions, a different set of factors may have affected the Table VIII performance during each phase of the research. This possibility is discussed in more detail in the next section of the report.

Although there were differences between the mean total scores for Phases I and II, the variance and distribution of the scores for each phase were similar. This indicates that restriction of range in the criterion variable was not a problem in this research.

Another possible explanation for the failure of the predictor model derived in Phase I to cross-validate or replicate in Phase II is that Table VIII may be an unreliable criterion, since one prerequisite for obtaining a high correlation between predictor and criterion variables is a reliable criterion measure. To test the feasibility of this explanation, an estimate of the internal consistency of Table VIII average total score was calculated independently for each phase, using the ten Table VIII tasks as items. For Phase I and Phase II, respectively, the αs were .58 and .49. Thus, unreliability of the criterion measure does not appear to be a significant problem in this research. That the reliability of each of the Table VIIIs approaches or exceeds .50 is surprising in itself, since Table VIII is designed to cover a rather broad and heterogeneous set of crew gunnery skills.

Relationship Between Predictor and Performance Measures

A somewhat ironic finding of the research was that crews achieved higher scores on their first run on Table VIII during Phase II even though these crews attained lower reticle aim levels in the crew matrix. This finding is evidence that the two battalions used U-COFT differently during their training leading up to Table VIII. The two battalions that participated in Phase I had mileage restrictions for training that were imposed by the division. That is, a limit was placed on the number of miles that each tank could be driven during the gunnery cycle. As a result of this limit, crews could participate in only one Tank Table IV exercise (the Tank Crew Proficiency Course or TCPC) during their gunnery training cycle. This gunnery event allows crews to dry-fire from stationary and moving tanks or to use Telfare, a subcaliber device that substitutes for the main gun. Moreover, the distance that the crews traveled during the TCPC was restricted to 5 miles. The relatively poor performance on Table VIII during Phase I is evidence that the mileage and TCPC limitations interfered with normal gunnery training.

Given that the two battalions participating in Phase I were restricted in the amount of gunnery training received on actual tanks, their training on U-COFT probably accounted for a larger proportion of their total gunnery training. If so, then the relatively high relationship between level of performance on U-COFT and first-run Table VIII performance would be expected. On the other hand, given that the four battalions that participated in

Phase II had none of the training restrictions that were present during Phase I, their U-COFT training probably accounted for a smaller proportion of their total gunnery training. To the extent that TCPC exercises contributed to overall gunnery skills, then the lack of a relationship between level of performance on U-COFT and first-run Table VIII performance during Phase II would not be surprising.

Summary and Conclusions

During Phase I of this research, a relationship was found between U-COFT performance and first-run performance on Table VIII, with crew turbulence as a suppressor variable. This relationship was not obtained during Phase II, however. This discrepancy between the two sets of results could have been due to differences in gunnery training during Phases I and II. The battalions participating in Phase I were restricted to one TCPC, but those participating in Phase II had no TCPC restrictions. Thus, U-COFT may have played a larger role in training during Phase I than during Phase II.

The fact that the anticipated relationship between the predictor and performance variables was obtained during Phase I, but not during Phase II, suggests that it may be possible to overcome the effects of future reductions in ammunition allocations. Mileage restrictions interfered with normal gunnery training during Phase I. The existence of these restrictions may inadvertently have caused Phase I to be a more accurate reflection of future training conditions than Phase II. If so, then more credence can be given to the Phase I results than to the Phase II results.

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Appendix A

U-COFT Matrices

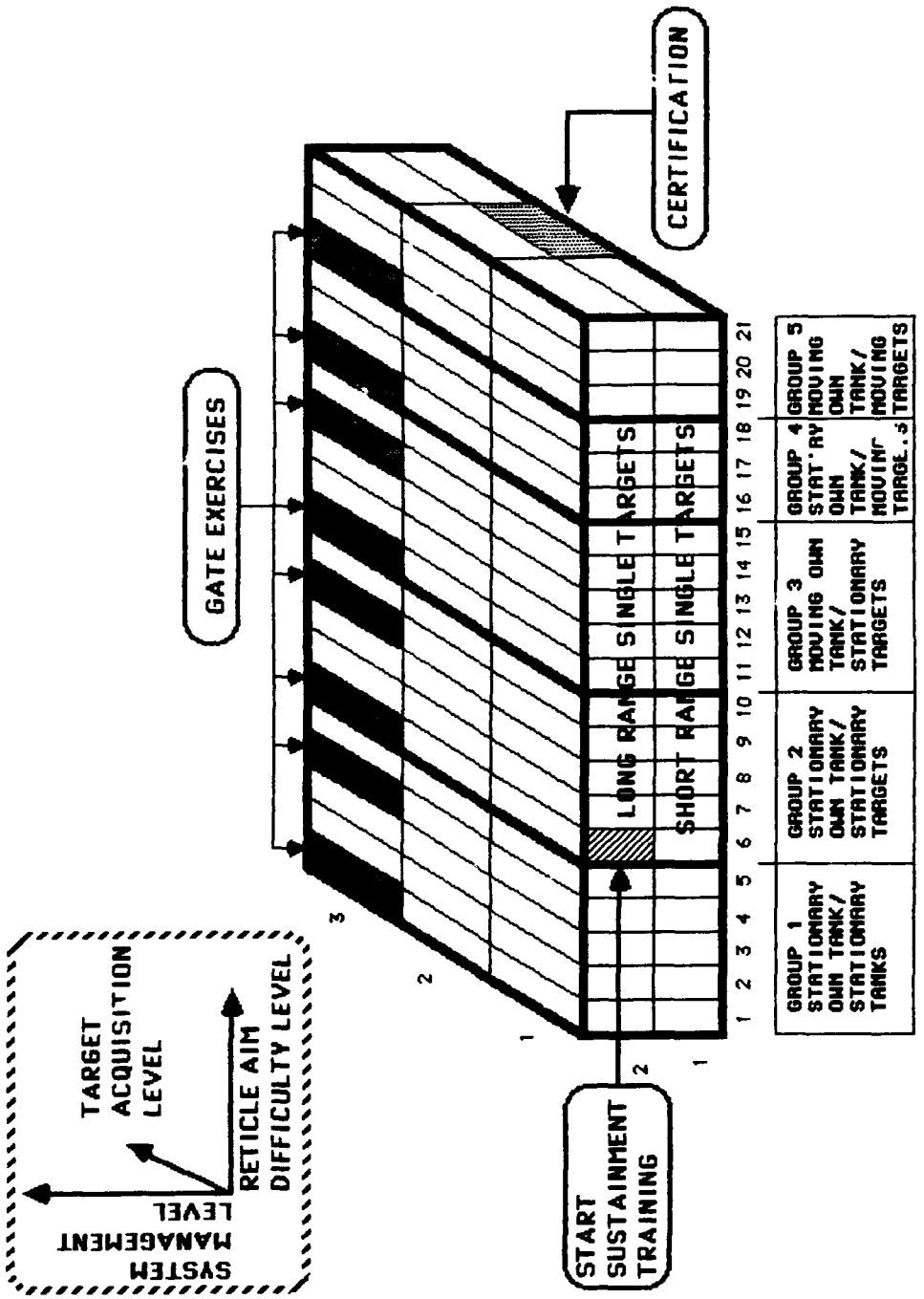

Figure A-1. M1 U-COFT TC training matrix.

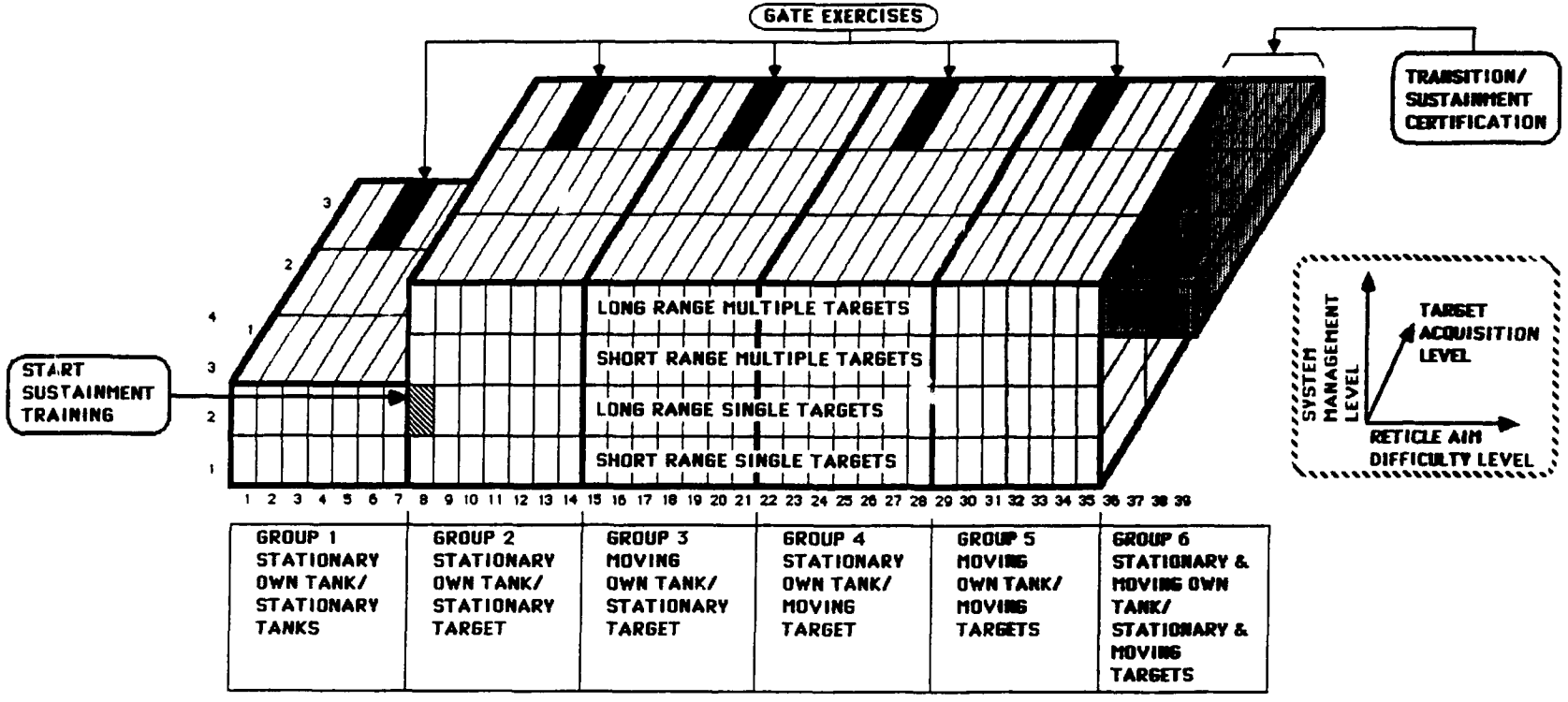

Figure A-2. M1 U-COFT crew training matrix.

Appendix B

Procedures for Calculating Overall and Main Gun Performance Variables

Table B-1

Procedures for Calculating Overall and Main Gun Performance Variables

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FOR EACH TASK:

From the Table VIII scoresheet, record the following information:

1. Raw score
2. Crew cuts
3. Total score
4. Opening time = time for first round (machinegun or main gun)
5. Number of targets presented
6. Number of targets hit
7. Time for last main gun round fired
8. Number of main gun rounds fired
9. Number of main gun targets hit

Using the information recorded above, calculate:

10. Task firing rate = (main gun rounds fired ÷ time for last round) x 60.

    Note: task firing rate is multiplied by 60 to facilitate interpretation.

11. Task hit proportion = main gun targets hit ÷ main gun rounds fired.

(table continues)

ACROSS TASKS:

Using the information recorded and calculations made for each task, calculate the following performance measures:

12. Average raw score = sum of raw scores divided by the number of engagements included in the analyses.

13. Average cuts = sum of crew cuts divided by the number of engagements included in the analyses.

14. Average total score = sum of total scores divided by the number of engagements included in the analyses.

15. Average opening time = sum of opening times divided by the number of engagements included in the analyses.

16. Percent hits = total number of targets hit divided by the total number of targets presented.

17. Firing rate = task firing rate weighted by the number of main gun targets in the task.

    For each task multiply the task firing rate by the number of main gun targets presented. Sum the resulting value across tasks and divide by the total number of main gun targets presented. That is,

    $$\text{Firing rate} = \frac{\Sigma(\text{task firing rate} \times \text{main gun targets in task})}{\Sigma(\text{main gun targets})}$$

    where Σ = sum across tasks.

18. Hit proportion = task hit proportion weighted by the number of main gun targets in the task.

    For each task multiply the task hit proportion by the number of main gun targets presented. Sum the resulting value across tasks and divide by the total number of main gun targets presented. That is,

    $$\text{Hit proportion} = \frac{\Sigma(\text{task hit proportion} \times \text{main gun targets in task})}{\Sigma(\text{main gun targets})}$$

    where Σ = sum across tasks.

19. Hit rate = firing rate x hit proportion.